PB-230 606

WATER RESOURCES ACTIVITIES IN THE UNITED STATES. FUTURE WATER REQUIREMENTS FOR MUNICIPAL USE

Select Committee on National Water Resources, U. S. Senate

January 1960

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

PB 230 606

86th Congress
2d Session

COMMITTEE PRINT NO. 7

WATER RESOURCES ACTIVITIES
IN THE
UNITED STATES

RECEIVED
LIBRARY
AUG 2 1968
FWPCA, OHIO BASIN REGIO
CINTI. O.

FUTURE WATER REQUIREMENTS FOR MUNICIPAL USE

SELECT COMMITTEE ON NATIONAL WATER RESOURCES
UNITED STATES SENATE

PURSUANT TO

S. Res. 48

EIGHTY-SIXTH CONGRESS

JANUARY 1960

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

Printed for the use of the Select Committee on National Water Resources

---

UNITED STATES
GOVERNMENT PRINTING OFFICE
49589 WASHINGTON : 1960

SELECT COMMITTEE ON NATIONAL WATER RESOURCES

(Pursuant to S. Res. 48, 86th Cong.)

ROBERT S. KERR, Oklahoma, *Chairman*
THOMAS H. KUCHEL, California, *Vice Chairman*

DENNIS CHAVEZ, New Mexico
ALLEN J. ELLENDER, Louisiana
WARREN G. MAGNUSON, Washington
CLINTON P. ANDERSON, New Mexico
HENRY M. JACKSON, Washington
CLAIR ENGLE, California
PHILIP A. HART, Michigan
GALE W. McGEE, Wyoming
FRANK E. MOSS, Utah
JAMES E. MURRAY, Montana, ex officio

MILTON R. YOUNG, North Dakota
ANDREW F. SCHOEPPEL, Kansas
FRANCIS CASE, South Dakota
THOS. E. MARTIN, Iowa
HUGH SCOTT Pennsylvania

PAUL MCBRIDE, *Chief Clerk*
THEODORE M. SCHAD, *Staff Director*

STATEMENT BY THE CHAIRMAN

DECEMBER 29, 1959.

To the Members of the Senate Select Committee on National Water Resources:

Senate Resolution 48 directs our committee to study the extent and character of water resource activities, both governmental and nongovernmental, that can be expected to be required to provide the quantity and quality of water for use by our population and industry between the present time and 1980. With the increasing trend toward urbanization, the furnishing of water through municipal water systems is assuming ever-increasing importance. In our lifetime we have seen a tremendous increase in the number of people served by municipal water systems, which, coupled with a large increase in per capita use, has compounded the problems experienced by cities in supplying their residents with adequate supplies of clean, fresh water.

At the turn of the century about 30 million people had the advantage of a municipal water supply and were using some 3 billion gallons a day. In 1954, the number of people supplied by municipal systems had increased to over 100 million using a total of over 16 billion gallons of water daily. This is at an average rate of nearly 150 gallons per capita per day with a maximum rate of over 200 gallons per day per person in some communities.

In order to provide the committee with information relating to what we may expect in the municipal water supply field, I asked the Public Health Service of the Department of Health, Education, and Welfare to prepare a report for the committee covering present and projected future use of water for municipal purposes in the United States for the years 1980 and 2000. The report prepared by the Public Health Service shows that from a recorded figure of 16⅔ billion gallons per day in 1954, with per capita use of 147 gallons, anticipated water use from municipal systems in the continental United States, under assumed medium rates of population growth, may be conservatively projected to 29 billion gallons a day in 1980, and to 43 billion gallons a day in the year 2000. Under assumptions calling for a high rate of population increase, this water use is projected to about 33 billion gallons per day in 1980 and 58 billion gallons per day by 2000, at slightly lower per capita rates. The report goes on to point out that if certain stimulants of municipal use continue to occur, these figures may increase to as high as 43 billion gallons a day in 1980 and 88 billion gallons a day in the year 2000, with per capita use of 185 gallons per day in 1980 and 225 in the year 2000.

This report will be of great interest to you, to other Members of the Senate, and to all who are interested in our finding solutions to our future water problems, and therefore, I am having it printed as one of our series of committee prints dealing with all aspects of water resources activities in the United States.

The Public Health Service is also reporting to the committee on pollution abatement and on water quality management as a means of improving the usefulness of available water resources, and these reports will be made available later.

ROB'T. S. KERR,
Chairman, Select Committee
on National Water Resources.

COMMUNICATIONS

JUNE 24, 1959.

Hon. ARTHUR S. FLEMMING,
Secretary of Health, Education, and Welfare,
Department of Health, Education, and Welfare,
Washington, D.C.
(Attention of Leroy E. Burney, Surgeon General, Public Health Service).

MY DEAR MR. SECRETARY: Reference is made to my letter of June 15, 1959, concerning the work of the Select Committee on National Water Resources. Among the other facets of the committee's work on which an early start must be made is preparation of materials relating to municipal water use and to the use of water for pollution abatement. Among the Federal agencies working in the water field the committee believes that the Public Health Service has unique qualifications for dealing with these matters. Accordingly, it is requested that reports on these two subjects be prepared for this committee by the Public Health Service.

The first of these reports should give us information relating to water use and related matters along the following lines:

1. Per capita water use for domestic, commercial (to include industrial service normally supplied through municipal water systems), and municipal public purposes. We would, like to have information on 1959 or another recent year, some information on past trends, and projections on use in 1970, 1980, and 2000. We would like to have this information broken down by State with specific consideration given to major metropolitan areas, in particular Albuquerque, Boston, Chicago, Dallas-Fort Worth, Houston, Kansas City, Los Angeles, New York, Philadelphia, Phoenix, San Francisco, and Washington, as well as any other municipality having unusual problems.

2. Discussion of expected changes in rate of water use giving components of the changes.

3. Relation of cost to use of water and any other information which will throw light on supply-demand relationships for water.

4. Description of major problems in municipal water supply which may be anticipated from projected water use trends covering particularly municipalities or metropolitan areas having unusual problems.

5. Discussion of most efficient municipal water service and use at minimum levels of water consumption.

6. Any other matters in the field of municipal water use in relation to other uses of water which the Public Health Service believes should be brought to the attention of the committee.

The second report should give us information on present pollution hazards and projections of future pollution hazards, generally as follows:

1. Estimated extent of water pollution from industrial water use by type, source, and stream, at present and in 1970 and 1980, with an appraisal of recent effects on water quality by major industrial classification and type of effects. Trends should be discussed and specific examples should be cited. For this category we are concerned primarily with pollution of an inorganic character.

2. Extent of stream and underground water pollution by organic material from municipal sewage and other sources at present and in 1970 and 1980, considering population increases, sewage treatment trends, and other pertinent factors.

3. An estimate of the present extent of avoidable sediment load originating on land with a disturbed vegetative cover, by stream, with comments on the relationship of this type of pollution to other pollution hazards.

4. An appraisal of the extent to which streams should function as waste carriers by 1980.

Preceding page blank

5. Estimated requirements for water pollution control measures to 1970 and 1980, with recommended measures.

6. Any other matters in this field which the Public Health Service believes should be brought to the attention of the committee.

We would like this information to be made available in the form of two reports of not more than 10,000 words each, with whatever tables, charts, appendixes, and graphic illustrations as may be considered necessary. It would be most helpful if this information could be furnished the committee by October 1, 1959.

The committee staff will be happy to discuss any problems that may arise in the preparation of this material with representatives of the Public Health Service.

Sincerely yours,

ROB'T. S. KERR,
Chairman.

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE,
PUBLIC HEALTH SERVICE,
Washington, D.C., December 21, 1959.

Mr. TED SCHAD,
Senate Select Committee on National Water Resources,
New Senate Office Building,
Washington, D.C.

DEAR MR. SCHAD: In his letter of June 24, 1959, to Secretary Flemming, Senator Kerr requested that the Public Health Service prepare for the use of his committee a report on "Future Municipal Water Supply Requirements in the United States," and another report on the "Use of Water for Pollution Abatement Purposes." A list of six questions on each of these two subjects was contained in Senator Kerr's letter as suggestive of the kind of coverage desired.

In assembling and preparing the information requested, we have become more and more convinced of the inseparability of the water supply and waterborne waste disposal problems, as demands upon the rivers of the United States increase. Accordingly, in preparing the material for the use of the committee, we have come to visualize our report essentially as a presentation and discussion of the overall problem of total water quality management in relation to the projected national requirements for water for all legitimate purposes. Our report has, therefore, been prepared with this concept in mind. For convenience, in dealing with the subject, however, the report has been subdivided into three parts.

Part I presents estimates of future municipal water requirements in continental United States and discusses the relationship of these requirements to total available supplies and total future demands. Part II presents data on present and future pollution loadings on our streams, and discusses the sources of these loadings. Part III discusses the implication of the data presented in parts I and II from the point of view of total water needs for all other purposes, and presents observations and suggestions with respect to what is required to attain overall water quality management as a means of insuring an adequate future water supply for all purposes.

Because of the urgency of the committee's requirements, part I of our report, entitled "Future Municipal Water Supply Requirements," is submitted herewith. As parts II and III are completed, it may be found desirable to modify part I in order that the whole report will present a consistent and coordinated discussion of the whole subject. The final report in its completed form will, of course, probably be transmitted to Senator Kerr officially by Surgeon General Burney, but the parts are being made available to you in this manner in order to expedite your committee's work.

Sincerely yours,

KEITH S. KRAUSE,
Chief, Technical Services Branch,
Division of Water Supply and Pollution Control.

CONTENTS

	Page
Statement by the chairman	III
Communications	V

PART I. FUTURE MUNICIPAL WATER SUPPLY REQUIREMENTS

Urban population estimates used in projecting water requirements (tables 1–3)	1
Municipal water requirements (tables 4–9)	5
Chart 1. Projected total water use from municipal systems by water resource regions	6
Per capita water use	9
Total municipal water use	9
Chart 2. Projected total water use from municipal systems by States	10
Factors affecting municipal water consumption	11
Cost of municipal water supply services (tables 10–18)	11
Effects of efficient management upon municipal water use	13
Effects of price upon water consumption	16
Relationship of municipal water use to other uses and to total national water supply	17
Problems likely to affect provision of municipal water supplies	18
Deterioration of water quality	18
Lack of coordination between governmental units	19

APPENDIX

Descriptions of specific water supply problems in selected river basins and metropolitan areas:

Boston, Mass., Metropolitan District
Chicago, Ill.
Lake Michigan, southern tip
Columbia, S.C.
Denver, Colo.
Hartford, Conn., Metropolitan District
Nashville, Tenn.
New Orleans, La.
Nitro, W. Va.
North Branch Potomac River
Pacific Northwest
Rhode Island
Richmond, Va., Metropolitan Area
Southeast coastal area
Yadkin River Basin, N.C.
Washington, D.C., Metropolitan Area

LIST OF TABLES

Table 1. Projections of urban population in continental United States, by States.
Table 2. Projections of urban and rural population in continental United States by water resource region.
Table 3. Projections of urban and rural population in selected standard metropolitan areas within water resource regions.
Table 4. Projected total water use from municipal systems in continental United States by water resource regions.
Table 5. Projected per capita water use from municipal systems in continental United States by water resource regions.
Table 6. Projected total water use from municipal systems in selected standard metropolitan areas within water resource regions.
Table 7. Projected per capita water use from municipal systems in selected standard metropolitan areas within water resource regions.
Table 8. Projected total water use from municipal systems in continental United States, by States.
Table 9. Projected per capita water use from municipal systems in continental United States, by States.
Table 10. Projected total annual cost of water from municipal systems in continental United States, by water resource regions.

Table 11. Projected annual cost per person for water from municipal systems in continental United States by water resource regions.
Table 12. Cost per million gallons for water from municipal systems in continental United States by water resource regions.
Table 13. Projected total annual cost of water from municipal systems by selected standard metropolitan areas within water resource regions.
Table 14. Projected annual cost per person for water from municipal systems by selected standard metropolitan areas within water resource regions.
Table 15. Cost per million gallons for water from municipal systems by selected standard metropolitan areas within water resource regions.
Table 16. Projected total annual cost of water from municipal systems within continental United States, by States.
Table 17. Projected annual cost per person for water from municipal systems within continental United States, by States.
Table 18. Cost per million gallons for water from municipal systems within continental United States, by States.

FUTURE WATER REQUIREMENTS FOR MUNICIPAL PURPOSES

PART I OF THE REPORT OF THE DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE TO THE U.S. SENATE SELECT COMMITTEE ON NATIONAL WATER RESOURCES

Presented in this part of our report are data on the quantities and costs of water presently supplied through municipal water supply systems, estimates of the quantities and costs of water required for municipal purposes in the continental United States in 1980 and the year 2000, and observations on problems affecting municipal water supply. This information is broken down, where appropriate, by States, by major river-basin areas and regions, and by selected metropolitan areas within each region. Data for Alaska and Hawaii are not included because the surveys upon which the tables are based were completed before these two States were admitted to the Union.

URBAN POPULATION ESTIMATES USED IN PROJECTING WATER REQUIREMENTS

Population estimates used for projecting future municipal water requirements are shown in tables 1 to 3, inclusive. Those for the river basin and metropolitan areas (tables 2 and 3) were prepared by staff of Resources for the Future, a privately endowed research organization which is assisting the Senate select committee in its studies. These projections show low, middle, and high rates of possible future population growth. The State breakdown (table 1) was derived from census data on total statewide populations, and differs to some degree from the other projections, and also shows only the medium rate of growth. The year 1954 was selected as representing current conditions, rather than the actual current year 1959, because the earlier year was determined to be the latest year for which complete data relating to other aspects of national water requirements are available and would, therefore, serve the committee's purposes to greater advantage.

TABLE 1.—*Projections of urban population in continental United States, by States*

[Millions]

	1954	1980	2000
U.S. total	108.9	204.4	321.8
Alabama	1.6	2.8	4.2
Arizona	.6	2.2	3.9
Arkansas	.7	.8	1.0
California	10.6	26.5	44.3
Colorado	1.0	2.4	3.7
Connecticut	1.8	3.3	5.2
Delaware	.3	.7	1.3
District of Columbia	.8	1.0	1.4
Florida	2.4	8.3	14.5
Georgia	1.8	3.5	5.7
Idaho	.3	.6	.9
Illinois	7.3	12.4	18.8
Indiana	2.7	4.9	7.9
Iowa	1.3	2.1	3.2
Kansas	1.1	2.1	3.3
Kentucky	1.2	1.9	2.9
Louisiana	1.7	3.7	5.9
Maine	.5	.9	1.3
Maryland	1.8	4.7	7.4
Massachusetts	4.9	5.7	8.1
Michigan	5.3	10.7	17.4
Minnesota	1.8	3.4	4.8
Mississippi	.7	1.0	1.6
Missouri	2.8	2.9	4.3
Montana	.3	.6	.9
Nebraska	.7	1.2	1.8
Nevada	.1	.5	.6
New Hampshire	.3	.5	.6
New Jersey	4.7	8.7	13.2
New Mexico	.4	1.6	2.0
New York	13.8	20.2	29.5
North Carolina	1.6	2.9	4.8
North Dakota	.2	.3	.5
Ohio	6.4	11.4	17.8
Oklahoma	1.2	1.9	2.7
Oregon	.9	1.8	3.0
Pennsylvania	7.9	11.2	16.3
Rhode Island	.6	1.1	1.6
South Carolina	.9	2.0	3.3
South Dakota	.2	.4	.7
Tennessee	1.6	2.7	4.3
Texas	5.9	13.7	21.7
Utah	.5	1.2	2.1
Vermont	.1	.2	.3
Virginia	1.8	4.2	7.1
Washington	1.7	3.6	6.0
West Virginia	.7	.9	1.4
Wisconsin	2.2	3.9	6.0
Wyoming	.2	.3	.5

49589—60——2

TABLE 2.—*Projections of urban and rural population in continental United States, by water resource region* [1] [2]

[Millions]

Water resource regions [3]	1950		1960		Range	1970		1980		1990		2000	
	Urban	Rural	Urban	Rural		Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
United States	96.5	54.2	125.5	54.0	Low	145.4	51.2	166.1	47.7	185.6	44.2	201.4	40.5
					Medium	154.8	52.2	192.6	51.2	234.5	51.1	279.4	49.9
					High	170.7	55.7	229.8	58.6	303.2	62.1	390.2	62.5
New England	7.0	2.1	7.3	2.3	Low	7.7	2.5	7.7	2.6	7.6	2.6	7.2	2.7
					Medium	8.2	2.5	9.0	2.8	10.0	3.1	10.9	3.3
					High	8.9	2.7	10.9	3.2	13.3	3.7	15.8	4.3
Delaware and Hudson	16.5	4.0	20.1	3.3	Low	22.9	2.5	25.5	1.9	27.8	1.5	29.5	1.1
					Medium	23.9	2.6	28.2	2.1	32.7	1.7	37.2	1.3
					High	25.9	2.8	32.6	2.4	40.3	2.1	49.3	1.7
Chesapeake Bay	5.2	3.3	7.3	3.3	Low	8.5	3.0	10.0	2.8	11.5	2.6	12.8	2.3
					Medium	9.2	3.1	11.6	3.0	14.5	2.9	17.6	2.8
					High	10.2	3.4	13.9	3.5	18.6	3.6	24.4	3.7
Eastern Great Lakes	8.1	2.3	10.1	2.5	Low	11.5	2.6	13.0	2.6	14.6	2.6	15.8	2.5
					Medium	12.1	2.6	15.0	2.8	18.0	3.0	21.4	3.1
					High	13.2	2.8	17.4	3.2	22.9	3.6	29.6	4.1
Ohio	10.2	6.0	12.9	6.6	Low	14.3	6.7	15.8	6.7	16.9	6.6	17.5	6.3
					Medium	15.5	6.9	18.8	7.2	22.4	7.6	26.3	7.8
					High	17.3	7.4	22.9	8.2	29.9	9.2	38.4	10.2
Cumberland	.5	.7	.6	.7	Low	.7	.7	.7	.6	.6	.5	.6	.5
					Medium	.8	.7	.9	.6	1.1	.6	1.1	.6
					High	.8	.7	1.1	.7	1.5	.8	1.8	.8
Tennessee	1.2	1.6	1.6	1.5	Low	1.7	1.4	1.7	1.3	1.8	1.1	1.5	1.0
					Medium	1.9	1.4	2.2	1.4	2.6	1.3	2.9	1.2
					High	2.1	1.5	2.8	1.6	3.6	1.6	4.4	1.6
Southeast	7.0	9.4	10.1	9.6	Low	11.5	9.2	13.5	8.9	15.2	8.4	16.6	7.8
					Medium	12.8	9.6	16.9	9.6	21.4	9.7	26.4	9.7
					High	14.8	10.2	21.2	10.4	29.5	11.8	39.4	12.6
Western Great Lakes	7.9	3.4	10.0	3.7	Low	11.3	3.8	12.8	3.8	14.3	3.7	15.3	3.6
					Medium	12.0	3.9	14.9	4.1	18.1	4.3	21.6	4.4
					High	13.3	4.2	17.9	4.7	23.6	5.2	30.4	5.8
Upper Mississippi	6.0	4.6	7.5	4.8	Low	8.4	4.7	9.1	4.6	9.5	4.3	9.7	4.0
					Medium	9.1	4.9	11.0	4.9	13.0	5.0	15.0	5.0
					High	10.3	5.2	13.5	5.6	17.6	6.1	22.2	6.5
Lower Mississippi	1.7	2.4	2.2	2.3	Low	2.4	2.0	2.5	1.8	2.5	1.5	2.6	1.3
					Medium	2.7	2.1	3.2	1.9	3.7	1.8	4.3	1.6
					High	3.0	2.2	4.0	2.2	5.2	2.2	6.4	2.1
Upper Missouri	2.4	2.9	3.0	2.9	Low	3.3	2.7	3.5	2.5	3.5	2.2	3.5	2.0
					Medium	3.6	2.8	4.4	2.6	5.1	2.6	5.8	2.4
					High	4.1	2.9	5.5	3.0	7.1	3.1	8.8	3.2
Lower Missouri	1.3	.9	1.3	.9	Low	1.5	.8	1.5	.7	1.5	.6	1.4	.5
					Medium	1.7	.8	1.9	.7	2.0	.7	2.2	.6
					High	1.8	.9	2.2	.9	2.7	.8	3.1	.8
Upper Arkansas, White, Red	1.8	1.5	2.3	1.4	Low	2.7	1.2	4.0	1.0	5.2	.8	3.4	.7
					Medium	2.9	1.2	3.5	1.1	4.1	1.0	4.6	.9
					High	3.2	1.3	4.2	1.2	5.3	1.2	6.5	1.1
Lower Arkansas, White, Red	1.7	2.0	2.1	1.6	Low	2.2	1.3	2.2	1.0	2.2	.8	2.0	.6
					Medium	2.4	1.4	2.7	1.1	2.9	.9	3.0	.7
					High	2.8	1.5	3.3	1.3	3.8	1.1	4.2	1.0
Western gulf	4.4	2.5	6.5	2.1	Low	8.3	1.6	10.1	1.2	11.9	.9	13.3	.6
					Medium	8.7	1.6	11.3	1.3	14.1	1.0	16.8	.8
					High	9.4	1.7	13.1	1.5	17.4	1.2	22.5	1.0
Rio Grande-Pecos	.5	.5	.8	.4	Low	1.0	.4	1.2	.3	1.5	.3	1.8	.2
					Medium	1.0	.4	1.4	.4	1.9	.3	2.5	.3
					High	1.0	.4	1.7	.4	2.4	.4	3.4	.4
Colorado	.7	.5	1.2	.5	Low	1.7	.5	2.0	.4	2.5	.4	3.0	.4
					Medium	1.7	.5	2.4	.5	3.1	.5	4.0	.4
					High	1.9	.5	2.8	.6	4.0	.6	5.4	.6
Great Basin	.5	.3	.8	.3	Low	1.1	.3	1.4	.3	1.7	.3	2.0	.2
					Medium	1.1	.3	1.5	.3	2.1	.3	2.6	.3
					High	1.2	.3	1.8	.3	2.6	.4	3.6	.4
Pacific Northwest	2.7	1.9	3.8	2.1	Low	4.5	2.0	5.2	2.0	6.1	2.0	7.0	1.9
					Medium	4.8	2.1	6.2	2.1	7.9	2.2	10.1	2.3
					High	5.3	2.2	7.4	2.4	10.3	2.7	14.3	3.0
Central Pacific	4.0	1.0	6.3	.9	Low	8.3	.7	11.2	.6	14.1	.4	17.0	.3
					Medium	8.6	.7	12.3	.6	16.5	.5	21.2	.4
					High	9.3	.7	14.1	.7	20.3	.6	27.9	.5

See footnotes at end of table, p. 3.

TABLE 2.—*Projections of urban and rural population in continental United States, by water resource region*[1][2]—Continued

[Millions]

Water resource regions[1]	1950		1960		Range	1970		1980		1990		2000	
	Urban	Rural	Urban	Rural		Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
South Pacific	5.1	.3	7.8	.3	Low	9.9	.2	12.5	.1	15.1	.1	17.6	(4)
					Medium	10.2	.2	13.6	.1	17.5	.1	21.7	(4)
					High	10.9	.2	15.5	.1	21.3	.1	28.4	.1

[1] Figures exclude Armed Forces overseas as well as Alaska and Hawaii. Total for U.S. rural is built up from individual regions which in turn have been projected on the basis of 1940 to 1950 change in the percent rural population was of total population within equivalent water resource combinations of States. Urban populations were then obtained by subtracting rural populations from total population.

[2] Totals derived by adding individual items. Sum of U.S. minimum totals will be less than national minimum; sum of U.S. maximums will be greater than national maximum.

[3] High regional urban population obtained by subtracting low rural from high total; low regional urban population obtained by subtracting high rural from low total.

[4] Less than 50,000 inhabitants.

TABLE 3.—*Projections of urban and rural population in selected standard metropolitan areas within water resource regions*

[Millions]

	1940	1950	1960	Range	1970	1980	1990	2000
New England:								
Boston	2.18	2.37	2.65	Low	2.62	2.72	2.80	2.84
				Medium	2.69	2.94	3.25	3.51
				High	2.87	3.37	2.94	4.27
Hartford	.30	.36	.41	Low	.46	.50	.53	.55
				Medium	.48	.54	.61	.67
				High	.51	.62	.75	.88
Delaware and Hudson:								
New York	11.66	12.91	14.64	Low	16.02	17.34	18.55	19.53
				Medium	16.51	18.83	21.34	23.86
				High	17.70	21.44	25.93	31.23
Philadelphia	3.20	3.67	4.31	Low	4.82	5.30	5.72	6.09
				Medium	4.97	5.75	6.58	7.41
				High	5.33	6.55	8.00	9.70
Albany-Schenectady-Troy	.47	.51	.58	Low	.64	.69	.74	.77
				Medium	.65	.75	.85	.95
				High	.70	.85	1.03	1.24
Eastern Great Lakes: Detroit	2.38	3.02	3.91	Low	4.62	5.38	6.14	6.82
				Medium	4.75	5.84	7.09	8.40
				High	5.11	6.64	8.61	11.00
Chesapeake Bay:								
Washington	.97	1.46	2.21	Low	2.81	3.44	4.02	4.52
				Medium	2.93	3.72	4.64	5.59
				High	3.14	4.26	5.65	7.32
Richmond	.27	.23	.30	Low	.62	.76	.88	.99
				Medium	.65	.82	1.02	1.22
				High	.69	.94	1.24	1.60
Western Great Lakes:								
Chicago	4.82	5.50	6.65	Low	7.31	8.47	9.45	10.29
				Medium	7.70	9.19	10.83	12.56
				High	8.28	10.50	13.20	16.13
Lansing	.13	.17	.24	Low	.29	.34	.40	.46
				Medium	.30	.37	.45	.54
				High	.32	.43	.55	.70
Ohio:								
Cincinnati	.77	.90	1.15	Low	1.32	1.49	1.64	1.76
				Medium	1.36	1.61	1.89	2.17
				High	1.46	1.84	2.30	2.84
Indianapolis	.46	.53	.73	Low	.85	.98	1.09	1.17
				Medium	.89	1.06	1.25	1.44
				High	.95	1.21	1.52	1.89
Cumberland: Nashville	.26	.32	.39	Low	.46	.48	.49	.50
				Medium	.46	.51	.60	.61
				High	.49	.58	.70	.82
Tennessee: Chattanooga	.21	.25	.35	Low	.40	.44	.47	.49
				Medium	.42	.48	.54	.59
				High	.44	.55	.66	.77

TABLE 3.—*Projections of urban and rural population in selected standard metropolitan areas within water resource regions*—Continued

[Millions]

	1940	1950	1960	Range	1970	1980	1990	2000
Southeast:								
Birmingham	0.46	0.56	0.71	Low	0.89	0.92	01.03	01.12
				Medium	.83	1.00	1.18	1.39
				High	.89	1.13	1.44	1.81
Columbia, S.C.	.10	.14	.20	Low	.24	.28	.32	.36
				Medium	.25	.30	.37	.44
				High	.26	.33	.45	.58
Upper Mississippi:								
Cedar Rapids	.09	.10	.13	Low	.15	.17	.18	.19
				Medium	.16	.18	.21	.23
				High	.17	.21	.25	.31
St. Louis	1.63	1.68	2.12	Low	2.47	2.76	2.99	3.15
				Medium	2.55	2.99	3.45	3.89
				High	2.73	3.40	4.20	5.10
Lower Mississippi: New Orleans	.55	.68	.85	Low	.94	1.00	1.05	1.05
				Medium	.96	1.09	1.21	1.32
				High	1.02	1.23	1.47	1.72
Upper Missouri:								
Denver	.41	.56	.77	Low	.92	1.03	1.09	1.14
				Medium	.94	1.11	1.27	1.40
				High	1.00	1.27	1.54	1.84
Sioux City	.10	.10	.11	Low	.11	.11	.11	.11
				Medium	.11	.12	.13	.14
				High	.12	.14	.16	.18
Lower Missouri: Kansas City	.69	.81	1.01	Low	1.22	1.30	1.36	1.40
				Medium	1.27	1.41	1.53	1.63
				High	1.32	1.57	1.87	2.09
Lower Arkansas-White-Red: Little Rock	.16	.20	.25	Low	.28	.28	.28	.26
				Medium	.29	.31	.32	.32
				High	.31	.35	.39	.42
Upper Arkansas-White-Red:								
Oklahoma City	.24	.33	.45	Low	.54	.61	.67	.70
				Medium	.56	.67	.77	.86
				High	.60	.76	.92	1.12
Amarillo	.06	.09	.12	Low	.15	.17	.19	.20
				Medium	.16	.19	.22	.25
				High	.17	.22	.27	.32
Western Gulf:								
Houston	.53	.81	1.21	Low	1.59	1.98	2.34	2.62
				Medium	1.64	2.15	2.69	3.23
				High	1.75	2.44	3.26	4.24
Dallas	.40	.61	.93	Low	1.21	1.50	1.76	1.98
				Medium	1.24	1.63	2.03	2.43
				High	1.33	1.85	2.46	3.19
Fort Worth	.23	.36	.56	Low	.73	.92	1.08	1.22
				Medium	.76	.99	1.25	1.50
				High	.81	1.13	1.51	1.96
San Antonio	.34	.56	.74	Low	.94	1.16	1.36	1.52
				Medium	.97	1.26	1.57	1.87
				High	1.04	1.43	1.90	2.46
Rio Grande: Albuquerque	.07	.15	.23	Low	.31	.39	.49	.59
				Medium	.31	.44	.57	.75
				High	.34	.49	.70	.96
Colorado:								
Phoenix	.19	.33	.59	Low	.86	1.09	1.37	1.63
				Medium	.86	1.22	1.59	2.00
				High	.91	1.35	1.94	2.63
Grand Junction	.01	.01	.02	Low	.03	.03	.04	.05
				Medium	.03	.04	.05	.06
				High	.03	.04	.06	.07
Pacific Northwest:								
Portland	.50	.70	.96	Low	1.14	1.33	1.56	1.79
				Medium	1.17	1.45	1.79	2.22
				High	1.24	1.64	2.18	2.91
Spokane	.16	.22	.29	Low	.34	.39	.45	.51
				Medium	.35	.42	.52	.64
				High	.37	.48	.63	.84

TABLE 3.—*Projections of urban and rural population in selected standard metropolitan areas within water resource regions*—Continued

[Millions]

	1940	1950	1960	Range	1970	1980	1990	2000
Great Basin: Salt Lake City	0.21	0.27	0.37	Low	0.48	0.59	0.73	0.84
				Medium	.48	.62	.83	1.01
				High	.51	.72	1.01	1.33
Central Pacific: San Francisco	1.46	2.24	3.26	Low	4.11	5.46	6.76	8.23
				Medium	4.25	5.92	7.82	10.16
				High	4.56	6.74	9.53	13.26
South Pacific: Los Angeles	2.92	4.37	6.90	Low	8.98	11.52	14.14	16.56
				Medium	9.25	12.52	16.37	20.42
				High	9.87	14.20	19.91	26.72

MUNICIPAL WATER REQUIREMENTS

Data on 1954 municipal water use, and estimates of municipal water requirements for 1980 and 2000, based on the foregoing population projections, are shown in tables 4 to 9, inclusive. These figures were derived from the January 1, 1958, Public Health Service inventory of municipal water facilities in cities over 25,000. Total and per capita consumption figures for all cities were, of course, not available because the inventory does not cover the smaller cities. Arbitrary adjustments were, therefore, applied when it was felt that the figures from the inventory reports were not representative of all cities in the area concerned. Where no information was available, either the average for the basin or the State was used.

TABLE 4.—*Projected total water use from municipal systems in continental United States by water resource regions*

[Million gallons per day]

Water resource region	1954	1980		2000	
		Medium	High	Medium	High
New England	1022	1477	1724	2022	2789
Delaware and Hudson	2360	3753	4259	5301	6869
Chesapeake Bay	812	1440	1648	2193	2872
Eastern Great Lakes	1675	2763	3144	4052	5390
Ohio	1439	2374	2745	3471	4694
Cumberland	75	119	137	163	229
Tennessee	191	311	370	441	616
Southeast	998	1832	2148	2818	3826
Western Great Lakes	2052	3360	3860	4593	6612
Upper Mississippi	1075	1759	2033	2535	3433
Lower Mississippi	238	387	449	546	732
Upper Missouri	372	618	722	867	1190
Lower Missouri	180	279	316	368	491
Upper Arkansas, White, Red	251	419	477	581	760
Lower Arkansas, White, Red	225	341	391	432	566
Western Gulf	667	1275	1415	1907	2380
Rio Grande-Pecos	84	159	179	270	339
Colorado	187	397	449	647	831
Great Basin	172	345	390	579	736
Pacific Northwest	762	1402	1607	2262	2991
Central Pacific	733	1603	1807	2715	3476
South Pacific	1104	2175	2368	3420	4114
U.S. total	16,674	28,588	32,638	42,543	55,936

TABLE 5.—*Projected per capita water use from municipal systems in continental United States by water resource regions*

[Gallons per capita per day]

Metropolitan area	1954	1980		2000	
		Medium	High	Medium	High
New England	142	164	158	186	177
Delaware and Hudson	129	133	131	143	139
Chesapeake Bay	129	124	119	125	118
Eastern Great Lakes	184	184	181	189	182
Ohio	124	126	120	132	122
Cumberland	125	132	125	148	127
Tennessee	136	141	132	152	140
Southeast	116	108	101	107	97
Western Lakes	228	226	216	229	218
Upper Mississippi	158	160	151	169	155
Lower Mississippi	119	121	112	127	114
Upper Missouri	138	140	131	149	135
Lower Missouri	138	147	144	167	158
Upper Arkansas, White, Red	120	120	114	126	117
Lower Arkansas, White, Red	118	126	118	144	135
Western Gulf	121	113	108	114	106
Rio Grande-Pecos	120	114	105	108	100
Colorado	187	165	160	162	154
Great Basin	246	230	217	223	204
Pacific Northwest	231	226	217	224	209
Central Pacific	141	130	128	128	125
South Pacific	170	160	153	158	145
U.S. average	147	148	142	152	143

CHART 1

PROJECTED TOTAL WATER USE FROM MUNICIPAL SYSTEMS
BILLION GALLONS PER DAY

By · WATER RESOURCE REGIONS ·

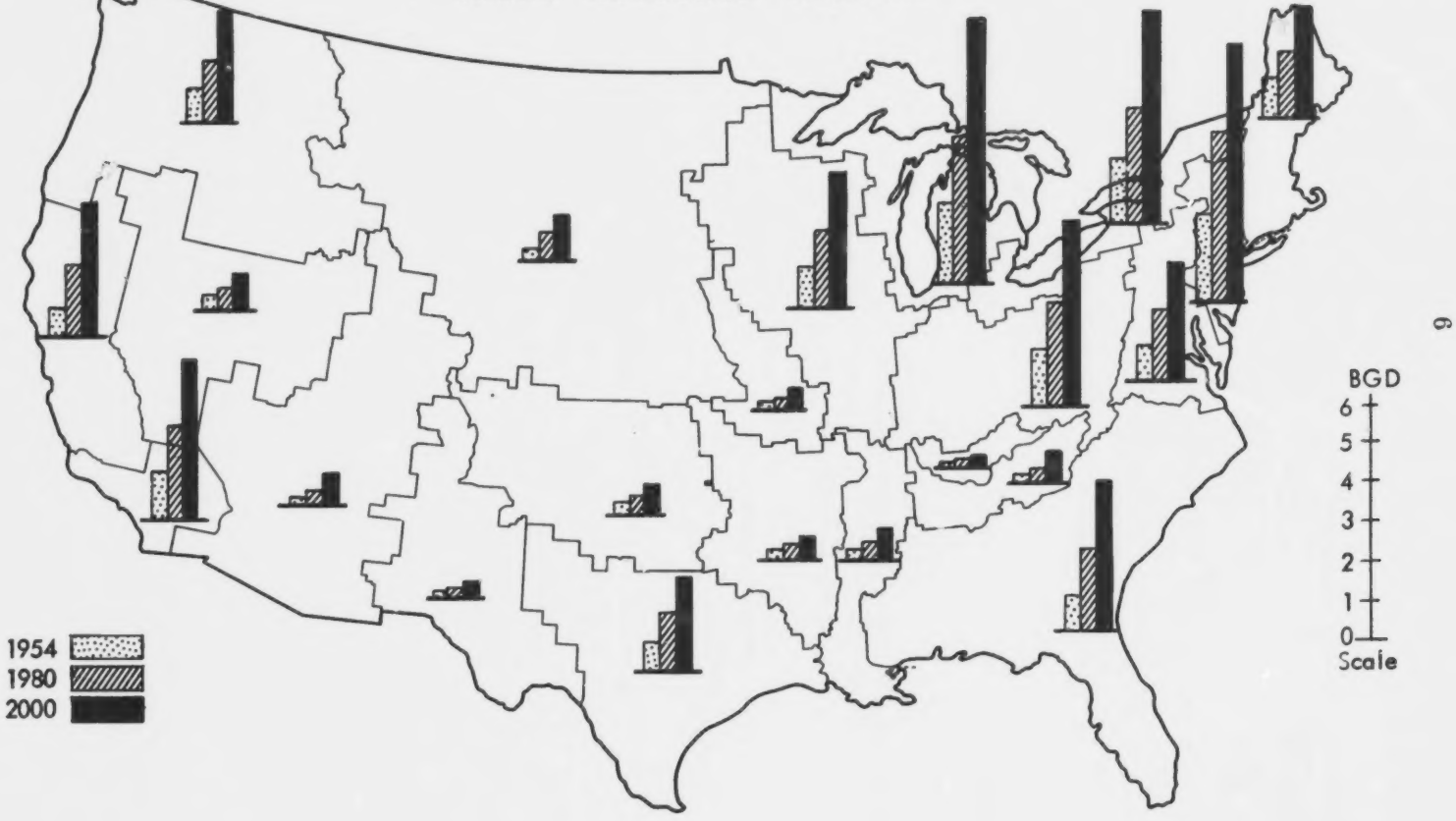


TABLE 6.—*Projected total water use from municipal systems in selected standard metropolitan areas within water resource regions*

[Million gallons per day]

Metropolitan area	1954	1980		2000	
		Medium	High	Medium	High
New England:					
Boston	268	388	446	534	717
Hartford	44	68	77	93	124
Delaware and Hudson:					
Albany-Schenectady-Troy	104	169	192	237	323
New York	2,880	4,248	4,757	5,837	7,519
Philadelphia	781	1,169	1,302	1,603	2,040
Eastern Great Lakes: Detroit	686	1,123	1,239	1,628	2,028
Chesapeake Bay:					
Richmond	56	103	114	154	189
Washington	246	359	515	696	885
Western Great Lakes:					
Chicago	1,381	2,174	2,462	3,128	4,100
Lansing	28	51	60	81	107
Ohio:					
Cincinnati	118	193	217	277	360
Indianapolis	78	135	153	194	256
Cumberland: Nashville	39	57	62	75	93
Tennessee: Chattanooga	37	63	73	90	122
Southeast:					
Birmingham	66	101	109	141	170
Columbia	17	30	34	44	56
Upper Mississippi:					
Cedar Rapids	15	24	28	33	44
St. Louis	396	635	718	896	1,172
Lower Mississippi: New Orleans	105	158	176	210	267
Upper Missouri:					
Denver	100	169	189	231	297
Sioux City	13	19	21	25	33
Lower Missouri: Kansas City	109	175	195	229	295
Lower Arkansas, White, Red:					
Little Rock	20	28	31	34	39
Upper Arkansas, White, Red:					
Amarillo	13	24	26	33	40
Oklahoma City	40	70	77	97	121
Western Gulf:					
Dallas	83	163	179	242	296
Fort Worth	50	99	108	150	184
Houston	95	189	208	287	356
San Antonio	84	161	180	244	308
Rio Grande-Pecos: Albuquerque	29	61	66	103	124
Colorado:					
Grand Junction	5	8	8	14	16
Phoenix	60	139	153	225	284
Pacific Northwest:					
Portland	104	185	206	287	363
Spokane	63	103	115	158	201
Great Basin: Salt Lake City	72	134	152	214	276
Central Pacific: San Francisco	345	702	788	1,183	1,500
South Pacific: Los Angeles	975	2,042	2,222	3,292	3,952

TABLE 7.—*Projected per capita water use from municipal systems in selected standard metropolitan areas within water resource regions*

[Gallons per capita per day]

Metropolitan area	1954	1980		2000	
		Medium	High	Medium	High
New England:					
Boston	111	132	132	152	157
Hartford	116	126	124	139	141
Delaware and Hudson:					
Albany-Schnectady-Troy	193	225	226	249	260
New York	209	226	222	245	241
Philadelphia	196	203	199	216	210
Eastern Great Lakes: Detroit	198	192	187	194	184
Chesapeake Bay:					
Richmond	133	126	121	126	118
Washington	133	97	121	125	121
Western Great Lakes:					
Chicago	227	237	234	249	250
Lansing	140	138	140	150	151
Ohio:					
Cincinnati	116	120	118	128	127
Indianapolis	122	127	126	135	135
Cumberland: Nashville	108	112	107	123	113
Tennessee: Chattanooga	123	131	133	153	158
Southeast:					
Birmingham	103	101	96	101	94
Columbia	100	100	97	100	97
Upper Mississippi:					
Cedar Rapids	125	133	133	143	142
St. Louis	208	212	211	230	230
Lower Mississippi: New Orleans	138	145	143	159	155
Upper Missouri:					
Denver	152	152	149	165	161
Sioux City	130	138	150	179	183
Lower Missouri: Kansas City	118	124	124	140	141
Lower Arkansas, White, Red:					
Little Rock	91	90	89	106	93
Upper Arkansas, White, Red:					
Amarillo	130	126	118	132	125
Oklahoma City	103	104	101	113	108
Western Gulf:					
Dallas	108	100	97	100	93
Fort Worth	109	100	96	100	94
Houston	94	88	85	89	84
San Antonio	135	128	126	130	125
Rio Grande-Pecos: Albuquerque	153	139	135	137	129
Colorado:					
Gand Junction	250	200	200	233	229
Phoenix	130	114	113	113	108
Pacific Northwest:					
Portland	125	128	126	129	129
Spokane	242	245	240	247	239
Great Basin: Salt Lake City	225	216	211	212	208
Central Pacific: San Francisco	125	119	117	116	114
South Pacific: Los Angeles	173	163	156	161	148

TABLE 8.—*Projected total water use from municipal systems in continental United States, by States (for medium-range population projections only)*

[Million gallons per day]

	1954	1980	2000
Total United States	16,674	28,588	42,543
Alabama	158	272	415
Arizona	105	319	564
Arkansas	53	69	94
California	1,565	3,583	5,906
Colorado	174	364	553
Connecticut	243	448	699
Delaware	35	93	158
District of Columbia	112	155	226
Florida	266	823	1,402
Georgia	224	416	656
Idaho	49	93	150
Illinois	1,248	2,107	3,206
Indiana	413	746	1,184
Iowa	144	237	360
Kansas	137	244	384
Kentucky	146	249	390
Louisiana	204	428	698
Maine	69	120	185
Maryland	236	523	857
Massachusetts	493	762	1,140
Michigan	1,129	2,064	3,240
Minnesota	193	343	540
Mississippi	69	114	177
Missouri	367	474	713
Montana	54	106	171
Nebraska	119	205	315
Nevada	38	122	214
New Hampshire	38	60	86
New Jersey	526	986	1,542
New Mexico	64	155	266
New York	1,904	2,997	4,516
North Carolina	169	312	507
North Dakota	18	29	45
Ohio	949	1,669	2,608
Oklahoma	158	253	365
Oregon	126	236	392
Pennsylvania	1,150	1,723	2,505
Rhode Island	70	121	183
South Carolina	100	197	317
South Dakota	25	45	70
Tennessee	188	322	504
Texas	702	1,518	2,418
Utah	121	248	401
Vermont	10	14	25
Virginia	175	380	629
Washington	332	674	1,114
West Virginia	82	125	190
Wisconsin	348	592	897
Wyoming	31	60	96

NOTE.—Sum of State figures does not add to totals for the United States because of different bases used in computing these 2 sets of figures.

TABLE 9.—*Projected per capita water use from municipal systems in continental United States, by States*

[Gallons per capita per day]

	1954	1980	2000
Total United States	147	148	152
Alabama	105	100	98
Arizona	170	143	141
Arkansas	81	88	90
California	147	135	133
Colorado	174	152	151
Connecticut	137	134	135
Delaware	142	126	125
District of Columbia	133	154	161
Florida	122	99	97
Georgia	127	119	117
Idaho	170	163	161
Illinois	171	169	170
Indiana	135	151	151
Iowa	110	113	114
Kansas	121	118	118
Kentucky	125	131	136
Louisiana	117	117	118
Maine	142	139	139
Maryland	131	117	116
Massachusetts	121	134	140
Michigan	213	193	187
Minnesota	108	111	113
Mississippi	107	110	113
Missouri	135	165	167
Montana	191	185	185
Nebraska	173	173	173
Nevada	270	230	226
New Hampshire	124	131	133
New Jersey	113	114	116
New Mexico	150	134	132
New York	138	148	153
North Carolina	108	106	106
North Dakota	101	98	100
Ohio	149	147	147
Oklahoma	130	134	138
Oregon	134	132	130
Pennsylvania	147	154	154
Rhode Island	111	110	114
South Carolina	108	98	96
South Dakota	107	101	99
Tennessee	118	119	118
Texas	119	112	112
Utah	223	200	194
Vermont	75	83	83
Virginia	100	90	89
Washington	196	187	185
West Virginia	112	127	132
Wisconsin	158	153	149
Wyoming	196	186	185

NOTE.—Averages of State figures are not the same as the national averages because of different bases used in computing these 2 sets of figures.

Per capita water use

The tables indicate that, on a national basis, municipal water use at the present time averages about 147 gallons per person per day, but that this use varies, region by region, from 100 gallons per person per day to as much as 250 gallons. An analysis of the 580 community water supplies covered, which serve 83,704,000 persons, indicates that 41 percent of this average daily per capita requirement is attributable to domestic use, 18 percent to commercial, 24 percent to industrial, and 17 percent to public use.

The pronounced regional and local differences in the per capita daily requirement result from differences in climate, size of city, industrialization, and other factors. For example, in 6 States having annual rainfall of less than 15 inches, the median per capita consumption was 210 gallons per day, while in 11 States with rainfall exceeding 45 inches, consumption was 119 gallons per day. As might be expected, urban areas in arid regions, such as Grand Junction, Spokane, and Salt Lake City, show a greater per capita requirement than do cities in the more humid areas. This is only a generality, however, and some of the larger metropolitan areas in the humid regions, such as Chicago, New York, and Philadelphia, also exhibit high consumption rates, but for other reasons, such as greater industrialization.

There is a tendency for States having the highest temperatures to also show higher per capita usage, probably because of increased air conditioning and lawn watering. Analyses of the effect of weather and climate on water use, carried on in both the United States and Australia, illustrate this point. Utilizing rainfall, temperature, relative humidity, and number of wet days, it was found that while rainfall was the factor having the most influence (the lower the rainfall the greater the consumption), the size of the community also has an effect on water demands. Communities of less than 100,000 population averaged 132 gallons per capita per day while the group over 100,000 averaged 150 gallons per capita per day probably reflecting increased industrialization.

In general, it may be noted that the present domestic use will probably average about 60 gallons per capita per day, commercial and industrial use about 65 gallons per capita per day, and public use about 25 gallons per capita per day, but that in specific instances, these quantities will vary widely depending upon climate, industrialization, and other influencing factors. Each area and region must be studied separately to ascertain its trends and requirements, based on climate and probable resources and other factors. It was, of course, impossible to make detailed analyses of each region and area in preparing the accompanying tables and the data represented is based on extrapolation of past trends and upon best judgments as to probable future requirements. The estimates are, if anything, on the conservative side and, as explained later, many factors could arise to stimulate much higher rates of water use, especially in particular areas.

Total municipal water use

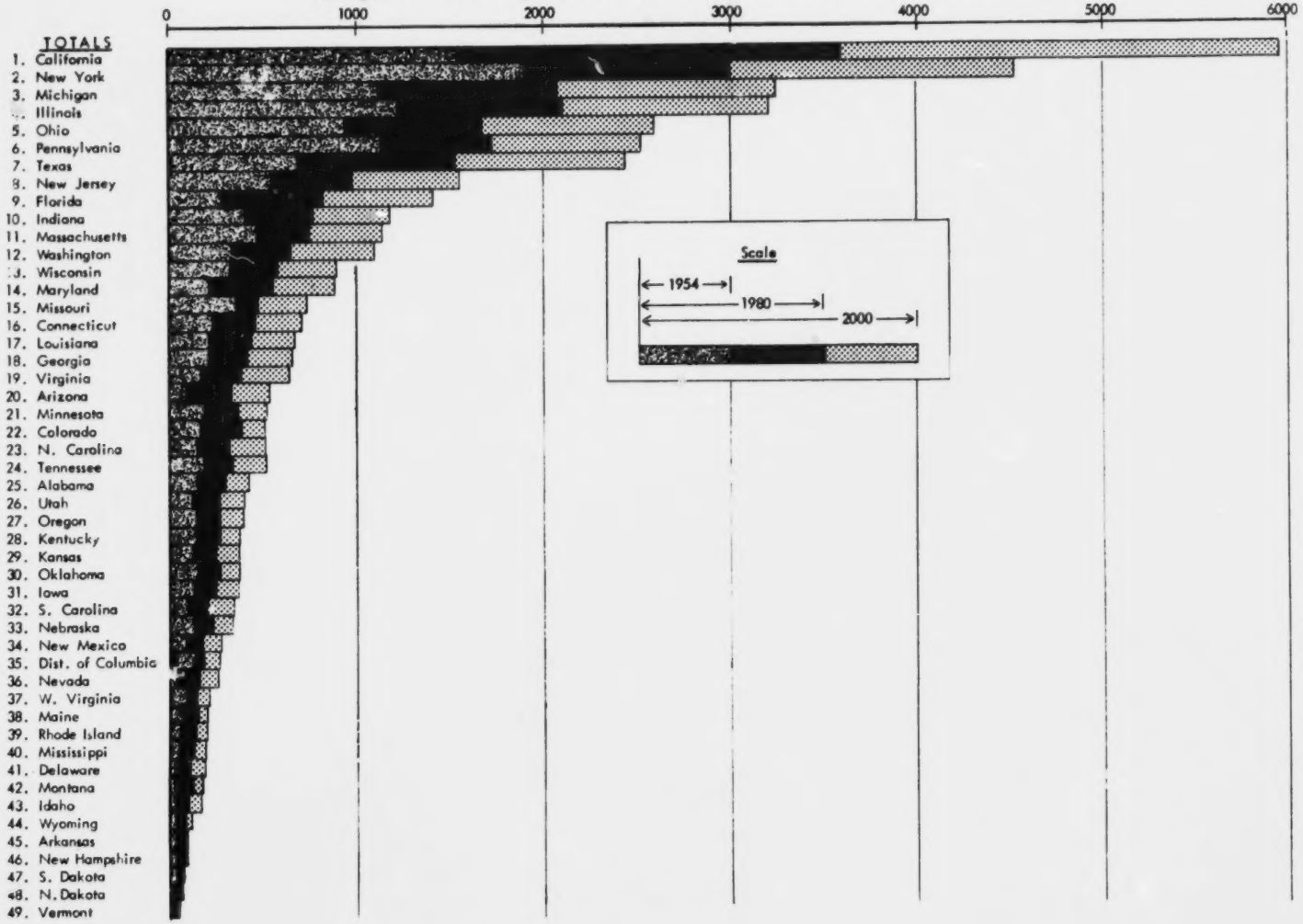
Population growth, in combination with per capita consumption, is the most important factor affecting total future municipal water requirements. The attached tables are based on both the middle and high estimates of future population increase. For most planning purposes, the middle rate, which assumes a total national population of about 330 million by the year 2000, is generally used. At this rate of growth, total municipal water requirements would amount to about 29 billion gallons per day in 1980 and 43 billion gallons per day in 2000. It is by no means certain that the medium rate of population growth will prevail, however, and it is believed that under certain social and economic conditions, population growth at the higher rate could take place. At the higher rate, the water requirements would reach 33 billion gallons per day and 56 billion gallons per day in years 1980 and 2000, respectively.

In the other direction, economic and other conditions could, of course, develop in such a way as to slow population growth in the same manner as occurred in the 1930's. Water demand would then accordingly be much less, and facilities planned on the higher rate would serve for even a longer period of time. Considerable judgment is, therefore, required in planning for future services, but an important consideration to be kept in mind is that, in developing public water supplies, it is essential that every precaution be taken in the interest of public safety and welfare. For these reasons, it is generally better to overbuild than to underbuild.

CHART 2

PROJECTED TOTAL WATER USE FROM MUNICIPAL SYSTEMS

Arranged in Descending Order by States for Years 1954, 1980 and 2000



FACTORS AFFECTING MUNICIPAL WATER CONSUMPTION

In addition to the possibility of a greater increase in population than that indicated by the middle group of figures, other factors could have a considerable stimulating influence on the amount of water required in the future for municipal purposes. New household devices, new industrial uses, urban rearrangements, or further improvements in living standards could result in substantial increases in per capita consumption. While the trends developed from the Public Health Service inventory of municipal water use indicate a recent leveling off in the per capita use of water in urban areas, prudent judgment suggests the desirability, therefore, of anticipating a possible resumption of the more rapid rate of increase in per capita consumption which could result from these new influences.

An analysis of possible increases in domestic consumption, which might result from a more widespread use of such devices as automatic clothes washers, suggests that domestic consumption could increase some 25 gallons per person per day above the present rate of 60 gallons. The tendency of cities in well-watered areas to continue to increase their consumption of water, as living standards increase, could continue for several decades. Provision of plentiful water supplies in cities in arid regions, which now have limited supplies, could have a stimulating effect on industrial growth, which in turn could stimulate still greater demands for water. Thus, when talking of future water development, the promotional impact of the development itself must be considered, especially as metropolitan concentrations in the East and Northeast become saturated. Migration of excess people to the Southwest, with attendant increase in industrial growth, could result in a substantial increase in average per capita water consumption.

Still another factor which could boost per capita water consumption is the tendency of industries to abandon their own sources of supply and to purchase water in increasing amounts from municipal systems. As wells and other sources available to them become polluted or destroyed, industries will, for economic reasons, seek more and more to connect with public systems. It is also anticipated that some of the larger industrial users will have to conserve their requirements and shift from their direct supplies to municipal supplies. This is particularly true of areas in which ground water supplies are being rapidly depleted.

Finally, it should be pointed out that there are process losses entailed in the development and distribution of municipal supplies, which make necessary improvement and processing of more water than is delivered to the point of use.

Counteracting foregoing indications of possible increases in municipal water consumption are conservation measures dictated by scarcity or cost. Recirculating of water used for air cooling, internal economies in industries, and other factors could reduce consumption somewhat in the future, but total growth is likely to more than offset such reductions.

Summarizing, it appears that the present 147 gallons per capita per day of average municipal use could, under the circumstances and conditions recited above, conceivably increase to about 185 gallons per capita per day in 1980, and to, perhaps, 225 gallons per capita per day in year 2000, with a possible leveling off thereafter. Should these higher per capita water requirements materialize, it would then mean that, at the medium rate of population growth, total municipal requirements would amount to 36 billion gallons per day in 1980 and 64 billion gallons per day in year 2000. If the higher population growth rate should occur, then these requirements would reach 43 billion gallons per day in 1980 and 88 billion gallons per day in year 2000.

COST OF MUNICIPAL WATER SUPPLY SERVICES

Tables 10 to 18, inclusive, contain data on the cost of supplying water to urban areas. These data are broken down by water resource regions, metropolitan areas, and States. They give total annual costs for each area or political subdivision, and also costs per million gallons and per person within each such subdivision. All costs include operation, maintenance, and amortization of investment costs.

TABLE 10.—*Projected total annual cost of water from municipal systems in continental United States by water resource regions* [1]

[Millions of dollars]

Basin	1954	1980		2000	
		Middle	High	Middle	High
New England	64.7	93.4	109.1	127.9	176.4
Delaware and Hudson	170.0	270.4	306.8	381.9	494.8
Chesapeake Bay	50.2	89.0	101.9	135.6	177.6
Eastern Great Lakes	98.0	161.7	184.0	237.1	315.4
Ohio	107.4	177.2	204.9	259.1	350.4
Cumberland	5.5	8.7	10.0	11.9	16.7
Tennessee	13.5	21.9	26.1	31.1	43.4
Southeast	75.2	138.0	161.8	212.2	288.1
Western Great Lakes	93.9	153.7	176.6	226.6	302.5
Upper Mississippi	57.1	93.4	107.9	134.5	182.2
Lower Mississippi	17.5	28.5	33.1	40.2	53.9
Upper Missouri	27.3	45.3	52.9	63.6	87.2
Lower Missouri	11.3	17.4	19.8	23.0	30.7
Upper Arkansas, White, Red	25.1	41.9	47.7	58.1	76.0
Lower Arkansas, White, Red	18.2	27.6	31.6	34.9	45.7
Western Gulf	57.0	109.0	121.0	163.1	203.5
Rio Grande-Pecos	8.6	16.2	18.2	27.5	34.6
Colorado	10.2	21.6	24.4	35.2	45.1
Great Basin	9.6	19.2	21.7	32.2	40.9
Pacific Northwest	40.9	75.2	86.2	121.4	160.5
Central Pacific	61.8	135.2	152.4	229.0	293.2
South Pacific	71.3	140.6	153.1	221.1	266.0
U.S. total	1,094.3	1,885.1	2,151.2	2,807.2	3,684.8

[1] Includes operation, maintenance, and amortization of investment cost.

TABLE 11.—*Projected annual cost per person for water from municipal systems in continental United States by water resource regions* [1]

[Dollars]

Basin	1954	1980		2000	
		Middle	High	Middle	High
New England	8.98	10.38	10.00	11.73	11.17
Delaware and Hudson	9.29	9.59	9.39	10.26	10.03
Chesapeake Bay	7.97	7.68	7.33	7.71	7.28
Eastern Great Lakes	10.77	10.78	10.57	11.08	10.65
Ohio	9.26	9.43	8.95	9.85	9.13
Cumberland	9.10	9.63	9.07	10.79	9.26
Tennessee	9.62	9.97	9.32	10.72	9.87
Southeast	8.74	8.16	7.63	8.04	7.31
Western Great Lakes	10.43	10.32	9.87	10.49	9.95
Upper Mississippi	8.39	8.49	7.99	8.96	8.21
Lower Mississippi	8.76	8.90	8.26	9.35	8.42
Upper Missouri	10.10	10.30	9.62	10.96	9.91
Lower Missouri	8.66	9.18	8.98	10.46	9.91
Upper Arkansas, White, Red	11.96	11.98	11.36	12.64	11.70
Lower Arkansas, White, Red	9.57	10.21	9.57	11.64	10.89
Western Gulf	10.37	9.65	9.24	9.71	9.05
Rio Grande-Pecos	12.23	11.58	10.73	11.01	10.16
Colorado	10.16	8.99	8.71	8.79	8.36
Great Basin	13.67	12.79	12.05	12.39	11.37
Pacific Northwest	12.39	12.13	11.65	12.02	11.22
Central Pacific	11.89	10.99	10.81	10.80	10.51
South Pacific	10.97	10.34	9.88	10.19	9.37
U.S. average	9.79	9.79	9.36	10.05	9.44

[1] Includes operation, maintenance, and amortization.

TABLE 12.—*Cost per million gallons for water from municipal systems in continental United States by water resource regions* [1]

[Dollars]

Basin	*1954*
New England	173
Delaware and Hudson	197
Chesapeake Bay	169
Eastern Great Lakes	160
Ohio	205
Cumberland	199
Tennessee	193
Southeast	206
Western Great Lakes	125
Upper Mississippi	145
Lower Mississippi	202
Upper Missouri	201
Lower Missouri	171
Upper Arkansas, White, Red	274
Lower Arkansas, White, Red	221
Western Gulf	234
Rio Grande-Pecos	279
Colorado	149
Great Basin	152
Pacific Northwest	147
Central Pacific	231
South Pacific	177

[1] Includes operation, maintenance, and amortization as of 1954.

No data are available on detailed breakdowns of total investment costs as such, but generalized figures indicate that, on an average, these investment costs amount to about $122 per person for the provision of complete water supply systems. This overall cost breaks down into $23 per person for development of source, $27 for treatment, and $72 for distribution.

The tables show that the annual costs of water per person averages close to $10 but varies from a low of about $6½ in Columbia, S.C., to a high of over $17 in San Francisco. Generally speaking, cities in the arid areas exhibit higher costs than do cities in the more humid regions, although there are exceptions, such as Detroit and Indianapolis. The higher costs in the western cities are due in part at least to the longer distances over which water must be transmitted, and the larger quantities used.

Data on costs per million gallons for municipal water vary from $103 in Chicago to $387 in San Francisco, but in general do not show the same regional pattern of differences as exhibitied in the figures for annual cost per person. The variations occur on an individual rather than a regional basis.

TABLE 13.—*Projected total annual cost of water from municipal systems by selected standard metropolitan areas within water resource regions* [1]

[Million dollars per year]

Metropolitan area	1954	1980		2000	
		Middle	High	Middle	High
New England:					
Boston	22.3	32.3	37.1	44.5	59.7
Hartford	2.9	4.5	5.1	6.1	8.2
Delaware and Hudson:					
Albany-Schnectady-Troy	5.2	8.4	9.6	11.8	16.1
New York	131.7	194.3	217.6	276.0	344.0
Philadelphia	38.6	7.7	64.3	69.2	100.8
Eastern Great Lakes: Detroit	40.3	65.9	72.7	95.6	119.1
Chesapeake Bay:					
Richmond	4.2	7.7	8.6	11.6	14.2
Washington	14.6	21.2	30.5	41.2	52.4
Western Great Lakes:					
Chicago	51.7	81.4	92.1	117.0	153.4
Lansing	2.0	3.7	4.4	5.9	7.8
Ohio:					
Cincinnati	10.0	16.3	18.4	23.5	30.5
Indianapolis	8.6	14.8	16.8	21.3	28.1
Cumberland: Nashville	3.5	5.1	5.5	6.7	8.3
Tennessee: Chattanooga	3.0	5.1	5.9	7.2	9.8
Southeast:					
Birmingham	6.7	10.3	11.1	14.4	17.3
Columbia	1.1	2.0	2.3	2.9	3.7
Upper Mississippi:					
Cedar Rapids	1.2	1.9	2.2	2.6	3.4
St. Louis	17.2	27.5	31.1	38.9	50.8
Lower Mississippi: New Orleans	6.5	9.7	10.8	12.9	16.4
Upper Missouri:					
Denver	9.6	16.2	18.1	22.1	28.4
Sioux City	1.0	1.4	1.5	1.8	2.4
Lower Missouri: Kansas City	8.4	13.4	14.9	17.6	22.6
Lower Arkansas, White, Red:					
Little Rock	1.9	2.7	3.0	3.3	3.7
Upper Arkansas, White, Red:					
Amarillo	.8	1.4	1.6	2.0	2.4
Oklahoma City	4.6	8.0	8.8	11.1	13.8
Western Gulf:					
Dallas	9.9	19.4	21.3	28.8	35.2
Fort Worth	4.9	9.7	10.5	14.6	17.9
Houston	7.6	15.2	16.7	23.0	28.5
San Antonio	6.6	12.6	14.1	19.1	24.1
Rio Grande-Pecos: Albuquerque	2.0	4.2	4.5	7.0	8.4
Colorado:					
Grand Junction	.2	.3	.3	.6	.6
Phoenix	4.6	10.7	11.8	17.3	21.8
Pacific Northwest:					
Portland	7.4	13.1	14.6	20.4	25.8
Spokane	2.9	4.8	5.3	7.3	9.3
Great Basin: Salt Lake City	3.6	6.6	7.5	10.5	13.6
Central Pacific: San Francisco	48.7	99.2	111.3	167.1	213.1
South Pacific: Los Angeles	58.9	123.4	134.3	199.0	238.9

[1] Includes operation, maintenance, and amortization of investment cost.

EFFECTS OF EFFICIENT MANAGEMENT UPON MUNICIPAL WATER USE

An efficient municipal water service should provide for the basic demands of the community without wastage or loss, and at reasonable cost. The water must be of acceptable quality from the standpoint of its biological, chemical, and physical properties, and be readily available under adequate pressures at points of demand.

There are certain water system management practices that can be undertaken to control water consumption. Leakage surveys, inspection of plumbing, and metering, coupled with consumer

TABLE 14.—*Projected annual cost per person for water from municipal systems by selected standard metropolitan areas within water resource regions* [1]

[Dollars]

Metropolitan area	1954	1980		2000	
		Middle	High	Middle	High
New England:					
Boston	9.26	10.98	11.02	12.66	13.06
Hartford	7.62	8.28	8.17	9.13	9.27
Delaware and Hudson:					
Albany-Schenectady-Troy	9.59	11.22	11.24	12.42	12.97
New York	9.56	10.32	10.15	11.19	11.01
Philadelphia	9.66	10.04	9.81	10.68	10.38
Eastern Great Lakes: Detroit	11.64	11.28	10.95	11.37	10.80
Chesapeake Bay:					
Richmond	10.00	9.42	9.09	9.46	8.86
Washington	7.87	7.51	7.16	7.37	7.16
Western Great Lakes:					
Chicago	8.50	8.85	8.77	9.32	9.34
Lansing	10.16	10.01	10.13	10.89	11.16
Ohio:					
Cincinnati	9.80	10.15	9.99	10.81	10.74
Indianapolis	13.38	13.98	13.88	14.79	14.87
Cumberland: Nashville	9.62	9.92	9.49	10.92	10.07
Tennessee: Chattanooga	9.90	10.54	10.65	12.24	12.72
Southeast:					
Birmingham	10.50	10.28	9.82	10.33	9.56
Columbia	6.64	6.65	6.45	6.65	6.42
Upper Mississippi:					
Cedar Rapids	9.73	10.38	10.38	11.17	11.05
St. Louis	9.04	9.21	9.16	9.99	9.97
Lower Mississippi: New Orleans	8.50	8.92	8.80	9.79	9.55
Upper Missouri:					
Denver	14.50	14.57	14.24	15.79	15.45
Sioux City	9.50	11.57	10.96	13.05	13.39
Lower Missouri: Kansas City	9.08	9.51	9.52	10.77	10.82
Lower Arkansas, White, Red:					
Little Rock	8.70	8.64	8.47	10.17	8.89
Upper Arkansas, White, Red:					
Amarillo	7.82	7.60	7.11	7.95	7.53
Oklahoma City	9.31	11.92	11.56	12.87	12.32
Western Gulf:					
Dallas	12.82	11.89	11.51	11.84	11.04
Fort Worth	10.60	9.75	9.32	9.75	9.15
Houston	7.54	7.05	6.83	7.12	6.73
San Antonio	10.60	10.00	9.85	10.21	9.80
Rio Grande-Pecos: Albuquerque	10.40	9.45	9.18	9.36	8.80
Colorado:					
Grand Junction	10.00	8.00	8.00	9.33	9.14
Phoenix	10.03	8.76	8.71	8.65	8.30
Pacific Northwest:					
Portland	8.90	9.06	8.92	9.18	8.86
Spokane	11.26	11.40	11.14	11.47	11.12
Great Basin: Salt Lake City	11.10	10.06	10.41	10.45	10.24
Central Pacific: San Francisco	17.72	16.75	16.51	16.45	16.07
South Pacific: Los Angeles	10.45	9.86	9.42	9.75	8.94

[1] Includes operation, maintenance, and amortization.

TABLE 15.—*Cost per million gallons for water from municipal systems by selected standard metropolitan areas within water resource regions* [1]

Metropolitan area	*Dollars*
New England:	
Boston	$228
Hartford	180
Delaware and Hudson:	
Albany-Schenectady-Troy	136
New York	125
Philadelphia	135
Eastern Great Lakes: Detroit	161
Chesapeake Bay:	
Richmond	205
Washington	162
Western Great Lakes:	
Chicago	103
Lansing	199
Ohio:	
Cincinnati	232
Indianapolis	301
Cumberland: Nashville	243
Tennessee: Chattanooga	220
Southeast:	
Birmingham	279
Columbia	182
Upper Mississippi:	
Cedar Rapids	213
St. Louis	119
Lower Mississippi: New Orleans	169
Upper Missouri:	
Denver	262
Sioux City	200
Lower Missouri: Kansas City	210
Lower Arkansas, White, Red: Little Rock	262
Upper Arkansas, White, Red:	
Amarillo	165
Oklahoma City	313
Western Gulf:	
Dallas	326
Fort Worth	267
Houston	220
San Antonio	214
Rio Grande-Pecos: Albuquerque	187
Colorado:	
Grand Junction	110
Phoenix	211
Pacific Northwest:	
Portland	195
Spokane	127
Great Basin: Salt Lake City	135
Central Pacific: San Francisco	387
South Pacific: Los Angeles	166

[1] Includes operation, maintenance, and amortization as of 1954.

education, will control wastage. Such a program is reported to have reduced consumption in one city from 300 to 234 gallons per person per day. Metering merits general consideration. An analysis of 1,474 communities showed that where less than 50 percent of the community was metered, the per capita consumption averaged 174 gallons per day versus 143 gallons per capita per day in communities over 99 percent metered. A form of metering used in some foreign countries to reduce consumer consumption is insertion of restrictive orifices in consumer connections. Many foreign

TABLE 16.—*Projected total annual cost of water from municipal systems within continental United States, by States* [1]

[Millions of dollars]

	1954	1980	2000
Total	1,094.3	1,885.1	2,151.2
Alabama	13.1	22.5	34.4
Arizona	6.0	18.3	32.4
Arkansas	5.8	7.6	10.4
California	118.9	272.3	448.8
Colorado	14.6	30.4	46.3
Connecticut	19.0	35.0	54.7
Delaware	1.6	4.4	7.4
District of Columbia	6.9	9.5	13.9
Florida	26.4	73.3	124.9
Georgia	14.2	26.4	41.6
Idaho	4.2	7.9	12.7
Illinois	61.9	104.5	159.0
Indiana	27.7	50.1	79.5
Iowa	12.4	20.4	31.1
Kansas	13.2	23.5	37.1
Kentucky	7.7	13.1	16.3
Louisiana	14.0	29.4	48.0
Maine	2.6	4.5	7.0
Maryland	11.7	25.9	42.4
Massachusetts	34.7	53.6	80.2
Michigan	62.3	114.0	178.9
Minnesota	12.3	21.9	34.5
Mississippi	5.5	9.1	14.1
Missouri	24.1	31.1	46.8
Montana	3.6	7.2	11.6
Nebraska	6.3	10.9	16.7
Nevada	1.9	6.1	10.7
New Hampshire	2.9	4.6	6.7
New Jersey	37.7	70.6	110.4
New Mexico	5.7	13.9	23.8
New York	132.3	208.3	313.9
North Carolina	14.1	26.0	42.3
North Dakota	2.0	3.2	5.0
Ohio	62.7	110.3	172.3
Oklahoma	14.3	22.8	32.9
Oregon	9.5	17.9	29.7
Pennsylvania	75.6	113.3	164.7
Rhode Island	5.0	8.6	13.0
South Carolina	6.2	12.2	19.6
South Dakota	2.6	4.6	7.2
Tennessee	16.0	27.3	42.8
Texas	62.5	135.3	215.4
Utah	8.1	16.7	27.0
Vermont	1.4	2.0	3.5
Virginia	11.9	25.9	42.9
Washington	20.9	42.5	70.2
West Virginia	6.3	9.7	14.7
Wisconsin	19.4	33.0	50.0
Wyoming	2.5	4.9	7.8

[1] Includes operation, maintenance, and amortization of investment cost.

NOTE.—Sum of State figures does not add to totals for the United States because of different bases used in computing these 2 sets of figures.

TABLE 17.—*Projected annual cost per person for water from municipal systems within continental United States, by States* [1]

[Dollars]

	1954	1980	2000
U.S. average	9.79	9.79	10.05
Alabama	8.68	8.28	8.15
Arizona	9.70	8.23	8.09
Arkansas	8.85	9.71	9.96
California	11.17	10.26	10.13
Colorado	14.54	12.69	12.64
Connecticut	10.68	10.51	10.60
Delaware	6.48	5.90	5.81
District of Columbia	8.22	9.43	9.85
Florida	10.88	8.85	8.63
Georgia	8.04	7.56	7.43
Idaho	14.41	13.84	13.60
Illinois	9.47	8.40	8.45
Indiana	10.39	10.15	10.11
Iowa	9.39	9.74	9.84
Kansas	11.70	11.37	11.38
Kentucky	6.60	6.05	5.65
Louisiana	8.07	8.03	8.14
Maine	5.21	5.24	5.23
Maryland	6.48	5.80	5.76
Massachusetts	8.50	9.43	9.84
Michigan	11.76	10.63	10.30
Minnesota	6.89	7.08	7.29
Mississippi	8.46	8.77	8.99
Missouri	8.87	10.84	10.96
Montana	12.76	12.52	12.50
Nebraska	9.16	9.15	9.16
Nevada	13.14	11.54	11.32
New Hampshire	9.16	9.98	10.13
New Jersey	8.07	8.14	8.33
New Mexico	13.23	12.00	11.79
New York	9.59	10.31	10.64
North Carolina	9.08	8.84	8.83
North Dakota	10.74	10.85	10.99
Ohio	9.83	9.71	9.69
Oklahoma	11.69	12.08	12.42
Oregon	10.18	9.96	9.88
Pennsylvania	9.66	10.14	10.12
Rhode Island	7.82	7.85	8.15
South Carolina	6.64	6.07	5.92
South Dakota	10.44	10.41	10.16
Tennessee	9.91	10.11	10.04
Texas	10.59	9.94	9.95
Utah	14.93	13.42	13.03
Vermont	10.25	11.54	11.62
Virginia	6.80	6.15	6.07
Washington	12.33	11.76	11.68
West Virginia	8.64	9.84	10.22
Wisconsin	8.81	8.51	8.31
Wyoming	15.72	15.21	15.10

[1] Includes operation, maintenance, and amortization.

NOTE.—Averages of State figures are not the same as the national averages because of different bases used in computing these 2 sets of figures.

countries also practice pumping for only a part of the day in order to reduce the water used. Such devices are intended to actually reduce the amount of water used, rather than prevent waste, and are not recommended for use in this country. Water is a relatively cheap and plentiful commodity in most areas of this country, costing from 5 to 10 cents per ton, delivered in the house, and there should be no limit on the amount furnished, provided the customer is willing to pay. As pointed out later, there is really plenty of water for municipal purposes, and the objective of metering should

TABLE 18.—*Cost per million gallons for water from municipal systems within continental United States, by States* [1]

	Dollars
Alabama	$227
Arizona	157
Arkansas	302
California	208
Colorado	229
Connecticut	214
Delaware	128
District of Columbia	168
Florida	244
Georgia	174
Idaho	232
Illinois	136
Indiana	184
Iowa	236
Kansas	264
Kentucky	144
Louisiana	188
Maine	103
Maryland	136
Massachusetts	193
Michigan	151
Minnesota	175
Mississippi	219
Missouri	180
Montana	185
Nebraska	145
Nevada	137
New Hampshire	209
New Jersey	196
New Mexico	245
New York	190
North Carolina	229
North Dakota	302
Ohio	181
Oklahoma	247
Oregon	207
Pennsylvania	180
Rhode Island	195
South Carolina	169
South Dakota	281
Tennessee	233
Texas	244
Utah	184
Vermont	382
Virginia	187
Washington	173
West Virginia	212
Wisconsin	153
Wyoming	224

[1] Includes operation, maintenance, and amortization.

be to prevent waste and to provide a basis for charging the customer for what he uses, not to deliberately restrict his consumption.

Leakage in water systems can also cause significant wastage; therefore, many systems are continually surveyed to locate and correct leakage. Systems with uncorrected defects may lose 15 to 20 percent of the supply. Well-managed municipal systems should maintain a continuous leakage survey.

Where water for municipal use is acquired under a State water right, the terms of the right can sometimes promote wasteful excess use of water. Water rights usually allow withdrawal of a specific amount of water, conditional upon a showing of beneficial use. Where continued right to the water depends on the quantity used in the past, there is, thus, a natural tendency to use all the water allowed, even if wastage should result. Under such circumstances, subsidized rates might even be used to encourage water use by consumers. Such a subsidy could be a flat rate for water service without metering, or extremely rapid reduction in price with increasing volume of use. As population increases, however, with increased total demand, it will become necessary to reduce per capita consumption, or to seek an increase in the amount of water allowed under the right. Possibly elimination of the subsidy would decrease per capita use, but some adjustment in the administration of such rights might also promote conservation of supply.

Increased use of sewer rental charges based on the amount of water used, as a method of financing sewerage and sewage treatment, has a tendency to increase water conservation and reduce the use of water. On the other hand, when sewer service charges are based on the strength of the sewage, there is a tendency to use more water for transportation of the wastes than is really needed in order to reduce the strength of the sewage.

EFFECTS OF PRICE UPON WATER CONSUMPTION

With most products, there is a relationship between price and demand; if the cost increases, the demand decreases. This is true also with water but the limits are not clearly defined. Water plays a unique role in that it is a vital necessity for life and yet is probably the cheapest commodity we buy, cheaper than dirt. Thus, should cost be even tripled, water would still be cheap and long-range domestic demand would probably not be significantly depressed. What this really means is that, except for minor fluctuations, prices charged for water have generally not reached the critical level where they would cause a marked reduction in consumption, although there are deviations from this generality with respect to industrial water use which will be discussed later. Another factor in the price structure is the political nature of this public utility. Proposals are sometimes made that price be used as a rationing or control device, especially in times of drought. Because of the political nature of public water departments, however, it is rarely possible arbitrarily to raise the price as a control measure. Furthermore, water is generally so cheap and so little is really known regarding the actual critical price level above which water use would be substantially curtailed, that this method of control has usually been foregone in favor of exercise of the police powers in those situations where water consumption actually had to be reduced. Using price as a means of curtailing water used under these circumstances would also be inequitable, since economically well-off citizens would probably continue to use all the water they wanted.

In those instances where a sharp price increase was established, the demand was depressed for a short time but tended to regain its former level. It has been reported that those communities having higher priced water experience a lower consumption rate, but the relationship is not at all clear and other factors such as water quality, metering, or system control, as a result of water scarcity, may be additional influencing factors.

The amount of municipal water used by industry varies considerably from community to community depending upon the number and types of industries. Since cost of industrial water is a part of the overall cost of product manufacturing, industry is more sensitive to price control. This is especially true where municipalities are charging industry sewer charges with surcharges based on volumes and strengths of discharged wastes. The cost of process waste plus disposal makes it economically attractive for industry to control and curtail water use. This has occurred in numerous instances. In addition, reevaluation by industry of its wet-processing methods have led to eco-

nomical modifications that require less water or result in in-plant water reuse. Some plants are also finding that introduction of water-conserving devices are actually yielding a profit through reduction of water bills. Many new industrial plants are also turning to air cooling instead of water cooling with savings in plant construction, maintenance, and operation in addition to curtailing water consumption.

Projecting these factors to the future—the year 2000—will indicate their influence on future water service. It may be expected that municipal water services will achieve reasonable efficiency, metering will be universal, and that adequate programs of leakage detection and plumbing inspection will have been instituted. Moderate price increases will have occurred reflecting increased costs of producing safe, potable water. These factors will tend to control domestic use to reasonable minimum levels. Unit use within each industry will be appreciably reduced but expanded industrialization will probably result in some increase in the industrial segment.

At present standards of usage, the average municipal per capita consumption of water will, therefore, increase slightly over present demands. As pointed out earlier, however, changes in living standards and other factors could push per capita use up substantially above these levels. The increase in population plus extending of water service to suburban areas will in any case increase greatly the gross water needs of the municipalities.

RELATIONSHIP OF MUNICIPAL WATER USE TO OTHER USES AND TO TOTAL NATIONAL WATER SUPPLY

The total amount of water which each year runs off the land surface of the continental United States is computed to be somewhere in the neighborhood of 1¼ trillion gallons per day. Assuming, as hydrologists have indicated, that it may be economically feasible ultimately to develop up to half of this amount for use for the various purposes which water serves, this would mean a gross national surface water supply of about 635 billion gallons per day. The total amount of ground water which can be developed on a sustained-yield basis is presently unknown, but we can assume that this might amount to enough at least to round the total of water available for all purposes to about 650 billion gallons per day.

Total water withdrawals for all uses in the United States today are estimated at somewhere around 280 billion gallons per day. Rough projections of overall demand suggest that this requirement will rise to around 600 billion gallons per day in 1980. No such projections to the year 2000 are yet available, but it does not appear unwarranted to assume that total demands could reach 1,000 billion gallons per day by that year.

Thus, it would appear, on the surface, that by year 2000 total water use could exceed the limits of the Nation's developable fresh water resources. This would not, in fact, be the case, however, because all of the various demands for water cannot simply be added together to indicate the water which must be supplied to meet these demands. Water is used many times over, for a variety of purposes, as it flows from its sources to the sea. Because of this fact, the actual amount of water required to meet all uses and demands is substantially less than the sum total of these demands. The actual quantity of water needed to meet these demands or, to put it another way, the total of various purposes which can be served by a given quantity of water, will vary from river basin to river basin, depending upon the kinds of uses involved, the climate, and upon what happens to the water as a result of use, but the amount of water involved can be materially less than the total sum of all withdrawals for such uses.

The tabulations of municipal water use included in this report have been developed on a conservative basis. They indicate that present average municipal water use is about 147 gallons per person per day, and suggest that it may never rise above 152 gallons per capita per day. On this basis, it is estimated that total municipal requirements will rise with population growth from the present 17 billion gallons per day to about 29 billion gallons per day in 1980 and 43 billion gallons per day in year 2000, if the medium level of population growth should prevail. If the high rate of population growth should, in fact, occur, however, total municipal demands would, on the basis of the foregoing per capita requirements, then reach 33 billion gallons per day in 1980 and 56 billion gallons per day in year 2000.

As was indicated earlier, however, there is no absolute assurance that per capita water consumption will remain at the levels indicated in our analysis of current trends. Should per capita

consumption rise to, perhaps, 185 gallons per day in 1980, as suggested in our previous discussion, municipal water requirements, at the medium level of population growth, would then total 36 billion gallons per day and at the high level, 43 billion gallons per day. If municipal water use should reach the level of 225 gallons per capita per day in year 2000, then total municipal withdrawals would amount to 64 billion gallons per day at the medium level of population growth and 88 billion gallons per day at the high level.

Assuming a maximum combination of all of the foregoing factors which could stimulate increases in municipal water demands, it appears possible then ultimately to achieve a total national demand for water supplied through municipal systems of somewhere around 85 to 90 billion gallons per day. In the light of present usage, such a demand seems exceedingly large. In reality, however, such a volume of water is only a relatively minor, although by no means insignificant, portion of the 650 billion gallons per day of water which may be available for ultimate total development. Here again, however, as with total water demand, a total municipal demand of 85 to 90 billion gallons per day does not necessarily mean that a total of that much water must be provided to meet this demand. Municipal water gets used over and over again, just as does water for other purposes. While certain large cities, such as New York, Los Angeles, and San Francisco now have virginal inland water supplies which, after being used once, are dumped into the sea, many other municipalities withdraw water from rivers which serve other cities both upstream and downstream. In these latter situations, most of the withdrawn water is returned to the river through the municipal sewer system, so that a portion, at least, of the water in each case is used several times over. This is true also of water withdrawn from Lake Michigan by Chicago, which after use, is discharged into the Chicago drainage canal, where it ultimately finds its way into the Illinois and Mississippi Rivers, serving other cities and other uses on the way. Except for the cases cited above, and a few others, it might be said that reuse is now, and will increasingly become, the rule, rather than the exception.

Considering the reuse factor described above, it would appear then that a possible outside total ultimate demand of 88 billion gallons of water per day for municipal purposes is not of itself a frightening figure. Something less than this amount would actually have to be provided, and since 88 billion gallons per day is, itself, only some 13 percent of the total water supply which may be available for development, and only 9 percent of possible maximum total demand for all purposes, in year 2000, it would appear that, for municipal purposes, we shall not be running out of water in a quantitative sense.

Where cities do run out of water, the difficulty in most instances, up to now, has been not so much a shortage of water as a shortage of vision. Water is, of course, very unevenly distributed in nature and must, in some areas, be transported long distances from place of occurrence to place of use. Even in such arid regions, however, it appears that additional supplies are still available for development within the limits of economic feasibility, especially when combined with other purposes in multiple-purpose developments. Projects such as the proposed California water plan, the central Arizona and central Oklahoma projects, and others, testify to this possibility. Even where additional water may not be available, it is often possible to divert water from other uses, such as irrigation, to that of municipal supply at a price which is not out of line with municipal water costs elsewhere. In most of the rest of the country, even these problems are diminished or nonexistent, and ample water is usually available for development. What is required in most instances is not more water as such but more forethought as to future needs and possibilities and the willingness to finance preparation of plans and the provision of the additional waterworks needed to bring the water to the people. The water, itself, is usually available.

PROBLEMS LIKELY TO AFFECT PROVISION OF MUNICIPAL WATER SUPPLIES

Deterioration of water quality

If for municipal purposes a shortage of water as such is not then impending, what are the problems which affect provision of future municipal water supplies? The greatest one is water quality. Cities are rapidly running out of clean water. Water is used for many purposes, and, in the process, is often polluted by both organic and mineral substances to such a degree that it is no longer fit for other uses such as municipal water

supplies, some industrial processes, irrigation, fish and wildlife, or recreation. In most instances, such polluted water can be cleaned up sufficiently for reuse for these purposes, but sometimes the pollution is of such a nature that it cannot be purified except at exorbitant expense, and must be discarded. Thus, where municipalities run out of water, it will usually not be because of a lack of water, but because the water available is unfit for use. The problem is not one of quantity, but of quality. In many areas of the country, this situation is becoming critical. This problem will be dealt with in greater detail in the following parts of this report, under the subject of "Water Quality Management."

Lack of coordination between governmental units

A second serious problem affecting the provision of water in urban areas stems from difficulties in the field of political structure or organization. These occur at two levels of government. At the State level, the problem results from the conflicting demands in adjacent States for water from rivers flowing across State lines. As an example, the city of New York is limited by Supreme Court action in the amount of water it can divert for its own use from the New York State portion of the Delaware River Basin, as a means of protecting the needs and claims of the downriver States of Pennsylvania, New Jersey, and Delaware. As demands in these lower States increase in the future, this problem will increase, and New York may, at some future time, be required to give up some of the water it is now withdrawing from the Delaware, and to substitute water from the nearby Hudson River.

Another similar situation involves the proposals of the city of Chicago to increase diversions from Lake Michigan, a proposal which is opposed by other lake States as well as Canada. While these proposals presently involve water for dilution of sewage effluents, the whole controversy involves problems of water supply from Lake Michigan, and may ultimately have to include consideration of the waters withdrawn for this purpose also.

These problems are largely legal in nature, but require full consideration of all technical possibilities, including possible results which may be achieved from needed research into new methods of disposing of wastes. A breakthrough in the development of new methods of treating and handling sewage and other wastes could have a profound effect upon the amount of water available for municipal and other uses.

In other areas of the country, interstate problems of water use which affect municipal supplies arise out of conflicts over the nature of proposed plans for the development and use of interstate streams. What is needed in most situations is a river-basin planning mechanism which can effectively coordinate such planning in order to assure optimum utilization of the river's resources on an equitable basis. The recently created Southeast Study Commission and the U.S. Study Commission, Texas, are two interesting attempts to deal with this problem, but a great deal more will eventually be required in this direction.

At the local level, provision of municipal water supply is handicapped in the larger metropolitan centers by the multiplicity of independent governments found in these areas. Among many others, Chicago and Washington are two interesting cases. In both instances water is supplied to various parts of each metropolitan area by several separate governmental agencies, which to some extent conflict or compete with each other, as well as with other interests concerned with other uses for the water body from which the water is procured. Some means is required in these areas for coordinating the operations of these numerous local governmental units so that planning for and providing public facilities and services in metropolitan areas will be placed on a more efficient, economical regionwide basis.

A number of Federal agencies have a direct interest in metropolitan areas because of the programs of assistance to local governments which they administer. In view of the prediction that by year 2000, over 85 percent of the Nation's people will be living in metropolitan complexes, it is suggested that Federal interest could be consolidated through interagency cooperation, and that congressional review of metropolitan problems might lead to solutions which would be highly beneficial not only with respect to water supply and sanitation functions but with respect to other public works and services as well.

Appendent as illustrations of the problems discussed in this report are descriptions of water supply situations and problems in a selected list of cities in the United States.

APPENDIX

DESCRIPTIONS OF SPECIFIC WATER SUPPLY PROBLEMS IN SELECTED RIVER BASINS AND METROPOLITAN AREAS

BOSTON, MASS., METROPOLITAN DISTRICT

Water supply in the Boston metropolitan area is handled by the metropolitan district commission, which was originally established by the legislature in 1895. Under existing legislation, the commission must supply water to communities within 10 miles of Boston and may supply others within a 15-mile radius of the statehouse if it proves economically feasible. The commission is also authorized to sell water from its reservoirs and aqueducts to those communities not otherwise eligible for membership in the district because of the 15-mile limitation. At present the commission supplies water at least partially to about 2 million people in 30 to 61 cities and towns within the 15-mile radius and to 10 additional communities west of the Boston metropolitan area, including 3 in the Chicopee River Valley. The water supply needs of the Merrimack River Valley, which are now under study, may result in the diversion of metropolitan district water to that area also.

The water is supplied from the 412-billion-gallon Quabbin Reservoir on the Swift River about 70 miles west of Boston through an aqueduct tunnel leading to the 67-billion-gallon Wachusett Reservoir on the Nashua River about 35 miles west of Boston. The estimated safe yield of the Quabbin-Wachusett Reservoirs is 335 million gallons per day, but because of diversions as indicated above the amount available to the metropolitan area does not greatly exceed 300 million gallons per day. The area's average use was 215 million gallons per day in the dry year of 1957. The Massachusetts Water Resources Commission has forecast a 60-percent rise in total water consumption for the year 2000, which means that the present water supply system of the metropolitan district commission will not be adequate and the area will require an additional source of water before that time.

In the studies and reports of 1895 and 1922, it was pointed out that water from the Millers, Westfield, and Deerfield Rivers may be considered for diversion to Quabbin Reservoir for future water supply needs.

CHICAGO, ILL.

Although the city of Chicago has supplied and will continue to supply water from its distribution system to communities surrounding the city proper, no overall plan has been promulgated to satisfy the ever-growing needs of the suburbs which are now supplied by wells. The ground water tables are dropping at a rapid rate in these suburban areas, and it is only a question of time before this overburdened source will have to be supplemented or replaced with the only alternate source relatively free of pollution, that is, Lake Michigan. The usual problems of the satellite town versus the mother city and the indifference on the part of the city have created walls built on legal jurisdictions which prevent the expansion of a unified, efficient water system. Two specific examples which illustrate this problem are the current programs being promoted by two water commissions representing several communities located to the west and northwest of Chicago proper. Each plans to take water from Lake Michigan at approximately the same location. Each is planning to build a separate transmission line and a separate 32-million-gallons-per-day treatment plant to serve areas which will in the not too distant future be contiguous. Coupled with this are conflicting engineering reports on the part of the city and these communities regarding the economics of obtaining water from Chicago. Clearly, a metropolitan water district possibly embracing the same area serviced by the Chicago Sanitary District would not only provide a solution to the duplication of effort on the part of the respective groups concerned, but would also provide a sound pattern for future expansion.

LAKE MICHIGAN, SOUTHERN TIP

Interstate relationships are affected by the constantly recurring taste and odor problems experienced by municipalities at the southern tip of Lake Michigan. Hammond and Whiting, Ind., have a continuous battle with taste- and odor-producing petroleum products in the raw water. When certain lake conditions prevail, these products affect the raw water quality at the Chicago South District filtration plant. For example, on one day in January 1959, the activated carbon usage to ameliorate taste and odor conditions was 110,000 pounds. Contrast this with a normal usage of approximately 6,000 in April 1959. In addition, the records at the Chicago South District filtration plant show that carbon usage has had an average increase over the past 10 years, thus indicating a worsening of the taste and odor problem.

COLUMBIA, S.C.

Columbia and 70 percent of the total industry in the State of South Carolina obtain water from the Broad and Saluda River Basins. It is expected that industry in the next decade will increase by $1 billion in plants, as it has done in the past decade. It is not expected that the

Preceding page blank

quantity of water will be a problem until far beyond the year 2000. However, deterioration in the quality of water is such that both streams are now classified "B."

The general pattern for industry and smaller communities is not to treat sewage and industrial wastes. The State health department and the water pollution control authority are deeply concerned about the increase in municipal and industrial wastes that will be discharged in the next decade to the Broad and Saluda Basins. It is predicted that unless there is complete treatment of all municipal and industrial wastes in the basins by 1980, the increase in pollution of these streams will render them unsuitable for public water supplies.

DENVER, COLO.

For purposes of long-range water supply planning, the Denver area could very well include the metropolitan complex from Fort Collins on the north to Pueblo on the south. This elongated region, bordering the front range of the Rocky Mountains, includes a number of cities and towns and covers 11 county jurisdictions.

Many local communities and districts in the Denver area independently plan and construct waterworks and sewerage facilities. Their efforts have been largely uncoordinated, even though common water sources and drainage courses are involved. With few exceptions, advance planning is not keeping pace with population growth and industrial expansion. Some local attempts are being made toward cooperative efforts in meeting water problems. Notable is the work of the intercounty regional planning commission in coordinating community planning. Also significant is the recent move by two cities, Colorado Springs and Aurora, to jointly develop and construct water supply works to serve their widely separated distribution systems.

HARTFORD, CONN., METROPOLITAN DISTRICT

The Hartford Metropolitan District supplies the water needs of the city of Hartford and 10 nearby towns. Extension of this service to other communities is being considered. To keep pace with past industrial and population growth, the district has developed two substantial water supply reservoirs in the Farmington River Basin. These reservoirs are expected to serve the district's needs until 1978, provided the service area is not enlarged It is estimated that by the year 2000 the need for water for domestic and industrial purposes will be 2½ to 3 times that of the present. Increased supplies may be obtained from additional ground water sources, improvement of water quality by pollution control, and improved methods of utilization. Large new sources, however, will be required and water supply reservoirs in the Farmington River Basin will undoubtedly carry the main burden. Investigations have therefore been made by the Corps of Engineers to determine the feasibility of providing additional water supply storage in the proposed flood control project on the West Branch of the Farmington River at the Colebrook River site. It has become evident that provision of flood control storage alone at this location would seriously handicap the development of the water supply potential of the watershed. District authorities have cooperated in this investigation, and have indicated that such development is highly desirable.

NASHVILLE, TENN.

The existence of some six or eight suburban areas, each with its own water supply, complicate the governmental pattern in the Nashville area. These suburban areas should all be incorporated into the Nashville water system so that construction and sanitary defects can be eliminated. An effort to adopt a metro government to meet these problems recently failed, because the outlying communities were suspicious of the city's motives. There is also the problem of supplying potable water to an extensive new residential and industrial area above Nashville, extending many miles along the Cumberland River.

It is expected that the capacity of the present treatment plant to serve the Nashville area must be doubled by 1980 and there is not space at the present site for this expansion. A new upstream site for the 1980 treatment works must therefore be found. This plant probably must be doubled in size again by the year 2000.

NEW ORLEANS, LA.

At the present time there is concern over the quality of municipal water taken from the Mississippi River at New Orleans. Deterioration in quality is due to the industrial wastes received by the river along its entire length (St. Louis, Memphis, Baton Rouge, etc.). These wastes are of unknown composition in many cases and may contain deleterious complex organic or metallic elements that may be harmful in minute quantities. These substances also may produce taste and odor problems. For many of these wastes, which may interfere with water quality, analytical methods of detection are unknown. Taste problems in New Orleans are severe. Continued efforts to detect undesirable constituents and to find methods of treatment will be required.

NITRO, W. VA.

The town of Nitro, W. Va., uses the Big Kanawha River as a source of water. A few miles above Nitro, at Charleston, lies a huge concentration of diversified chemical industry, particularly the organic chemicals manufacturing industry. The Kanawha River is relatively small and the flow in the river is controlled at a point above Charleston in such a manner as to meet hydroelectric requirements. The wastes going into the river are taste and odor producing. This causes taste and odor in the drinking water, destroys recreational fishing, and prevents the river from being used for recreational purposes. The water quality at Nitro is poor in spite of heroic efforts on the part of the water company to cope with the pollution. At Nitro, the water is sometimes of such quality that it can be diluted 100 times with odor-free water before the odor disappears.

NORTH BRANCH POTOMAC RIVER

Water problems on the North Branch Potomac River include the need for improvement in water quality and for the provision of adequate quantities for domestic and industrial use.

An adequate quantity of water from the North Branch is extremely important to industry. Chemical plants, a tire company, and a power company all require large amounts of cooling water. The present minimum flow of 93 cubic feet per second at Luke is not sufficient to allow for desired expansion by industry. A pulp and paper company at Luke is planning a plant expansion that will raise total water use to about 130 cubic feet per second, or 37 cubic feet per second more than the present minimum regulated flow. The power company has disclosed plans to build a large steam power plant on the North Branch approximately 4 miles below Keyser, W. Va. This plant will require a stream flow of 174 cubic feet per second for cooling purposes. A lack of adequate cooling water would require the company to construct cooling towers, which would increase construction and operating costs.

The basin of the North Branch of the Potomac River has great potential for industrial expansion which can be realized only if adequate quantities of good water are available. This can only be assured, however, by regulating the stream discharge. The Corps of Engineers has proposed a plan of reservoir construction in the North Branch Basin which would provide a minimum regulated flow of 350 cubic feet per second at Luke, Md. Realization of this plan is essential if demands for water for manufacturing, cooling, domestic water supply, power production, and pollution abatement are to be met.

PACIFIC NORTHWEST

Major cities in the States of Washington and Oregon have strong, well-equipped water supply organizations. Seattle, Tacoma, and Portland have extensive facilities in the Cascades, assuring them of a plentiful supply for the present and future. However, problems do exist with respect to the adequacy of transmission and distribution facilities. The reason for these inadequacies is the lack of timely action by the cities concerned in the face of population growth, annexation of new territory, and the need to service communities in the metropolitan territory adjacent to the central cities.

The adequacy of water supply facilities in the smaller communities surrounding the major cities is not satisfactory. The city of Portland services some 55 communities and water districts adjacent to its boundaries. There are, in addition, other close-in communities which have placed reliance on their own systems. These communities, unlike Portland, cannot afford to reach into the Cascades for an assured supply of water, and are forced to resort to small streams tributary to the Willamette River. Because this water must serve other purposes, particularly irrigation, there exists a constant struggle between the farmers and these small communities for the limited water sources. Adjudications of water rights by the State engineer is a slow and time-consuming process. Thus, although greater and greater expansion occurs in these small communities, the water supply situation remains in a haphazard, uncertain, and conflicting state.

RHODE ISLAND

The State of Rhode Island possesses extensive undeveloped water supply within its boundaries, offering potential security to present and prospective water users and inducement to industrial growth in future years. But these advantages are only potential, and will not be realized for the State as a whole unless appropriate policies, objectives, and programs are adopted for the full and economical conservation and utilization of this resource for the benefit of the entire area. Already the State is handicapped economically by shortages, undependability, and poor quality of water supplies in some of its cities and towns, as was emphasized by the drought in the summer and fall of 1957. Consulting engineers have determined that there will be an ultimate need for the development and utilization of all water resources of consequence in the State. This will be particularly important for the eastern communities of Pawtucket, East Providence, Newport, and Woonsocket.

The present population served by water supplies in Rhode Island is about 785,953, and the estimated population to be served by the year 2000 is 1,211,000. Whereas the present water consumption is slightly more than 100 gallons per capita per day, it is estimated that by the year 2001 this figure will reach 150 gallons per capita per day. On the basis of the present yield, this would produce a deficit of over 30 millions gallon per day at that time.

At the present time the water supply of the city of Providence has become a metropolitan supply, providing water to about half the population of the State. In general, the other water systems of the State are rapidly becoming outmoded. Additional supplies must be planned for the anticipated growth in underdeveloped areas of the State. The most desirable resources are not near the problem areas. Consolidation of management interests could easily lead to a rapid expansion in many areas now impeded in progress and retarded in potential expansion until suitable water service is provided.

RICHMOND, VA., METROPOLITAN AREA

The Richmond Metropolitan area shares with a number of similar parts of the Nation problems resulting from population growth and county urbanization.

This area, comprised chiefly of the city of Richmond and Chesterfield and Henrico Counties, has an estimated population of 435,000 for 1960 with a projected population of 600,000 by 1980. Greatest population pressure will be felt in that part of Chesterfield County close to Richmond, where population of one proposed sanitary district having an area of 42 square miles is expected to increase from the present 31,500 to 215,000 by the year 2000.

The city of Richmond takes its water supply from the James River. On occasion, flow in the James has been so low as to make it difficult to bring an adequate supply of water through the city's intake structures, and the city has exercised its right to take water from the Kanawha Canal, which is diverted water from the river at Bosher

Dam. In the not too distant future the city may install an intake structure of its own upstream from this dam.

Henrico County purchases water from Richmond for two-thirds of its 18,500 customers. Well supplies furnish the remaining customers.

Chesterfield County operates a 3-million-gallon-per-day water treatment plant and a distribution system serving approximately 35,000 persons. An emergency connection with the Richmond system was used extensively in the summer of 1959. Wells serve isolated areas, and water is purchased from Petersburg to serve a portion of the southeastern section of the county.

Chesterfield County has also joined with Petersburg, Colonial Heights, Norfolk, Newport News, and Portsmouth in financing a study of the Appomattox River Basin for the utilization of this river as a source of future water supply.

In order to conserve the waters of the James River and provide an adequate future water supply for the area, it probably will be necessary to construct dams and reservoirs upstream. A committee has been formed to take action in this direction. Water quality in the James River above Richmond has improved in recent years owing to the efforts of the Virginia Water Control Board and the cooperation of industries and municipalities. It is likely that through continued efforts on the part of all concerned water quality will improve even further.

SOUTHEAST COASTAL AREA

In the area below the "fall line" in Georgia (lower half of the State) and in virtually all of Florida, most of the water supply sources are from wells. Increasing use of well water has resulted in some salt water intrusion in all of the coastal cities of Georgia and Florida. In the Savannah, Brunswick, and St. Marys areas of Georgia, pumping of aquifers has produced increasing huge cones of depression extending in some cases 100 miles outward and 100 feet or more below the normal water level. The danger of salt water entering the fresh-water-bearing limestones increases each year.

In the lower coastal plain of the Southeast, the location of industry depends wholly on an adequate supply of water. The supply of well water is inadequate, and all but the major surface streams have virtually no low-water flow or are polluted by upstream communities. Water is inadequate for industry, for water power, for irrigation, or for stock water. Regulation of river flow through development of storage is needed.

YADKIN RIVER BASIN, N.C.

The Yadkin River Basin in North Carolina is an illustration of the growing need for comprehensive management of water resources to insure adequate quantities of good quality water to meet future growth and development. Rapidly growing population centers and an expanding economy exist within the basin. The presence of an ample supply of good quality water for domestic and industrial water supplies, electric power production, bathing and other forms of recreation, fish and wildlife propagation, agriculture, including livestock watering and irrigation, and waste disposal, has been and will continue to be a major factor in this development.

Recognition was given to the impending water problem and the need for regional planning of water resources utilization when seven cities retained consulting engineers to study the collective water needs of all of the communities. The engineers' study predicted a combined growth in population from 301,862 in 1956 to 816,000 in the year 2000. Corresponding water use would increase from 39 to 163 million gallons per day. The Yadkin River was proposed as the future raw water source. In 1958 a Public Health Service study indicated that maximum draft on the river by the year 2010 for municipal water supply, supplemental irrigation, and pollution abatement needs could be as high as 862 cubic feet per second. Minimum flow in the river has been recorded as 330 cubic feet per second; thus augmentation of low flow or storage will be required.

Legal difficulties may add to the complexity of the problem since the several cities looking to the Yadkin River for future water supply are not riparian owners. North Carolina water law is based on the riparian doctrine, and the legality of division of water by nonriparian owners may be questioned.

WASHINGTON, D.C., METROPOLITAN AREA

Use of the Potomac River for municipal water supply in the Washington Metropolitan area is essential. Problems associated with such a water supply include both the quantity and quality of the raw water source.

Estimated average consumption for the metropolitan area in 1980 is 447.6 million gallons per day and in the year 2000, 650 million gallons per day. Total dependable supply from sources other than the Potomac River is 98 million gallons per day. The minimum recorded flow in the Potomac River at Great Falls was 782 cubic feet per second or 506 million gallons per day. Total combined minimum dependable raw water supply without storage on the Potomac is, therefore, 604 million gallons per day if no consideration is given to demands for irrigation. Supplemental irrigation is just beginning to develop in this section of the country and in the Potomac River Basin will occur above the source of the District of Columbia water supply. Such use is consumptive in nature, since only a small fraction of the water withdrawn returns to the stream. Although studies of irrigation use in the basin are not yet complete, it has been estimated that potential demands on the river flow during critical months of drought are 350 million gallons per day in 1980 and 770 million gallons per day in the year 2000. If irrigation demand develops according to national trends, the dependable water supply could be exceeded by 1964. Water quantity then is an immediate major problem that must be reckoned with in the metropolitan area and must be resolved in the not too distant future. Ultimately, a reservoir will be needed to provide the necessary storage. Improvement or expansion of the District of Columbia water supply facilities must receive congressional approval.

Problems of water supply in the District of Columbia Metropolitan area are further complicated by the fact that water is processed and distributed in different parts of the area by several independent political jurisdictions.

○